2014 Sixth International Conference on Computational Intelligence and Communication Networks

Neural Network Based Method for the Diagnosis of Diabetic Retinopathy

Dipika Gadriye[1] Gopichand Khandale[2]

Department of Electronics Engineering, Wainganga College of Engineering, Nagpur, India
e-mail:dipikagadriye@gmail.com, gopikhandale@gmail.com

Abstract— **Diabetic Retinopathy is a severe and wide-spread eye disease, it is the main cause of blindness for the working age population in western countries. For the diagnosis of Diabetic Retinopathy, digital color fundus images are becoming increasingly important. This fact opens the possibility of applying image processing techniques in order to facilitate and improve diagnosis in different ways. As microaneurysms are earliest sign of DR, therefore an algorithm able to automatically detect the microaneurysms in fundus image captured is a necessary preprocessing step for a correct diagnosis. Some methods that address this problem can be found in the literature but they have some drawbacks like accuracy or speed. This system aims to develop and test a new method for detecting the microaneurysms in retina images. Gray level 2D feature based vessel extraction is done using neural network to do preprocessing. The method is evaluated on DRIVE database and prove to be superior than rule based methods. To identify microaneurysms in an image morphological opening and image enhancement is performed. A MATLAB implementation of the complete algorithm is developed and tests suggest that the diagnosis in an image can be estimated in shorter time than previous techniques with the same or better accuracy.**

Keywords— **DR, exudate, feature extraction, microaneurysms, neovascularization**

I. INTRODUCTION

Most of the people between age group 20-74 years, DR found to be the frequent cause of blindness. It progress gradually, starting with mild nonproliferative abnormalities, characterized by increased vascular permeability, and progressing through moderate and severe nonproliferative diabetic retinopathy (NPDR) characterized by vascular closure, to proliferative diabetic retinopathy (PDR) with the growth of new blood vessels on the retina and posterior surface of the vitreous. According to survey it is found that around 60 million people in india are diabetic among which youngster are more in number [1]. DR will become a more severe problem worldwide. As per data collected by World Health Organization 366 million people in the world will become diabetic by the year 2030 [2].

Diabetes has a significant economic impact on individuals, families, health systems and countries. For example, WHO estimates that in the period 2006 - 2015, China will lose $558 billion in foregone national income due to heart disease, stroke and diabetes alone [2]. In diabetic patients, early diagnosis and treatment can prevent visual loss and blindness. However, more than 50% of the diabetic patients over the world does not undergo any kind of eye checkup [3]. Whereas digital fundus photography of the human retina is proven to be both sensitive and specific in determining early sign of diabetic retinopathy.

Therefore access to such kind of screening services is an increasingly important issue. Therefore to increase access to screening, various research groups worldwide focus on the use of automated computer systems for determining what screened patients should be seen by an ophthalmologist and what patients can safely return for screening 1 year later. These types of automated systems have the potential to reduce the workload for screening ophthalmologists while maintaining a high sensitivity (i.e., above 90%) for the detection of patients with DR.The color fundus image of the retina in figure 1 shows various anatomical parts such as Optic Disc, fovea, blood vessels and abnormalities like hemmmorages, microaneurys and exudates. After these features were detected automatic diagnosis of the diabetic retinopathy (DR) can be done.

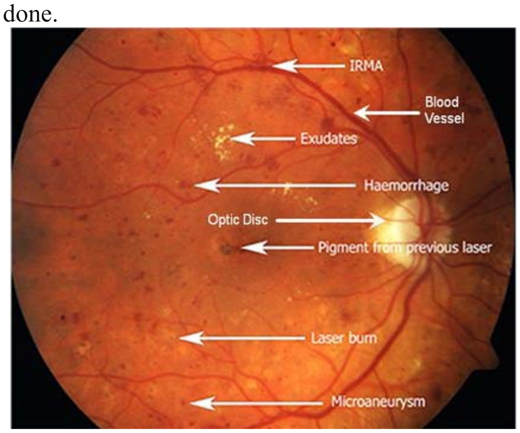

Fig 1. Fundus image of retina (Courtesy: The Eye Practice

In this paper, a new methodology for blood vessel detection presented by Marin et al. [9] is optimized for the MA detection. It is based on pixel classification using a 2-D feature vector extracted from preprocessed retinal images and given as input to a neural network. Classification results (real values between 0 and 1) are thresholded to classify each pixel into two classes: vessel and nonvessel. Finally, a postprocessing fills pixel gaps in detected blood vessels and removes falsely-detected isolated vessel pixels.

Despite its simplicity, the high accuracy achieved by this method in blood vessel detection is comparable to that reported by the most accurate methods in literature. It offers a better behavior against images of different conditions. This fact is especially relevant if we keep in mind that the main aim of implementing a vessel segmentation algorithm is its integration in systems for automated detection of eye diseases. This kind of systems should require no user interaction and, therefore, be field of retinal imaging, this involves a huge challenge, as a large variability is observed in the image acquisition process and a natural variation is reported in the appearance of the

978-1-4799-6929-6/14 $31.00 © 2014 IEEE
DOI 10.1109/CICN.2014.225

retina. Applications are being developed in which a computer interprets an image to aid a physician in detecting possibly subtle abnormalities. A spell-checker indicates words or grammar it suspects to be incorrect. This may or may not be the case and the human operator, the writer in this case, either accepts or rejects the machine's suggestions. A similar process can be used for medical image analysis. The computer indicates places in the image that require extra attention from the physician because they could be abnormal. These technologies are called Computer Aided Diagnosis. Other emerging CAD applications are the automatic detection of polyps in the large intestine and automatic lung nodule detection. This method describes components of an automatic system which can aid in the detection of diabetic retinopathy.This is an eye disease and a common complication of diabetes that can cause blindness and vision loss if left undiagnosed at an early stage. As the number of people afflicted with diabetes increases worldwide, the need for automated detection methods of diabetic retinopathy will increasel. To automatically detect diabetic retinopathy, a computer should interpret and analyze digital images of the retina.

II. MATERIALS

Fundus photography is the creation of a photograph of the interior surface of an eye, including the retina, optic disc, macula, and posterior pole. The fundus image of the retina is basically acquired with the digital fundus camera, which is a specialized camera that images the retina via the pupil of an eye. The fundus camera has the illumination system. Modern systems image at high-resolution and in color with Nikon or Canon digital SLR camera backends. The field of view (FOV) of the retina that is imaged can usually be adjusted from 25° to 60° (as determined from the pupil) in two or three small steps. The smaller FOV has better detail but this is at the expense of a reduced view of the retina [4].

There are various publicly databases which are available online for the research purpose such as Messidor database, STARE, DRIVE, DIARETDB1 Database and private database from hospital. The databases available are for the study , research purpose. In this databases various images along with annotation file is provided in which pathological result for each image such as retinopathy grade and features which are present such as micro aneurysm, exudates, hemorrhages, neovascularization is mentioned.

III. PROPOSED METHOD

A new DR diagnosis method is proposed. It is structured of various algorithms, some of which come from the literature and some others have been developed uniquely for this project. The preprocessing steps are introduced, followed by the feature extraction and finally by the training/classification steps. The proposed system gives an automated method for blood vessel enhancement and segmentation. The input retinal image normally contains too many background pixels which are not required for further processing.

IV. IMAGE PREPROCESSING METHODS

It is required because the photographer does not have complete control over the patient's eye so that retinal images often contain artifacts and are of low quality than desirable. In addition to that patients often have tears covering the eye and, particularly the elderly, may have cataract that obscures and blurs the view of the retina. In addition, patients often do not or cannot hold their eye still during the imaging process hence retinal images are often unevenly illuminated with parts of the retinal image brighter or darker than the rest of the image, or, in worst cases, washed out with a substantial or complete loss of contrast. Much more problematic is the uneven illumination of the retina, partly because it occurs more often, but also in part because in its extreme form can obliterate almost all the detail in a substantial part of the retinal image [4].The color image is basically consisting of red, blue and green channel. When monochromatic film was commonplace a blue-green filter was sometimes placed in the optical path of the fundus camera as the greatest contrast in retinal images occurs in the green wavelengths of light. Because retinal images are almost always saturated in the red channel and have very low contrast in the blue channel.

A. Detection of Retinal vessel

The detection of retinal vessel is important, as the severity of the disease and effect of the treatment can be determined by vessel detection [5]. There are lot of methods has been published for the blood vessel detection like 2D matched filter based approach [6]. The matched filter method is found to be more efficient than Sobel operator and morphological operator.

Diego Marin et al. [7] proposed a novel method for the segmentation of blood vessel in retinal image using gray level and moment invariant – based features. In that he uses neural network for the pixel classification and determines seven dimensional vectors composed of gray level and moment invariant based – features. It has been observed that the sensitivity of the matched filter can be optimized using genetic algorithm [8]. A 2-D Gabor wavelet based approach with supervised classification was used for the retinal segmentation. Based on the pixels feature vector the method classifies every pixel as blood vessel or non vessel and produces the required segmentations [9]. A Bayesian classifier with class-conditional probability density functions described as Gaussian mixtures were used which yielded a fast classification [10]. A neural network based approach using Principle Component Analysis was used in [11].

B. Detection of Neovascularization

The study of the blood vessel is very important for the detection of the neovascularization. Neovascularization is the appearance of new blood vessels in the fundus area and inside the optical disk which is the sign of proliferative diabetic retinopathy (PDR). So segmentation of blood vessel becomes important step to detect neovascularization.Akram et al. [12] have proposed the system which gives an automated method for the blood vessel enhancement and segmentation. A preprocessing algorithm given in [13] is applied to remove the background and noise from the image. It takes colored retinal image as a input. This algorithm uses 2D Gabor wavelet for vessel enhancement [9]. For vessel enhancement normally matched filters (MFs) [6] are used. The drawback is that MFs not only enhance blood vessels edges they enhance bright lesions. So 2D Gabor wavelet is best option due to its directional selectiveness capability of detecting oriented features and fine tuning to specific frequencies [14]. By performing subsequent iteration of decreasing threshold the segmented image is skeletonized to eliminate falls edges [6]. A window of size 15 x 15 is slided over segmented blood vessels in order to find abnormal vessels . For each position energy and density of blood vessels are computed. If they are more than the normal behavior of blood vessels then that segment contains abnormal blood vessel which is a sign of DR.

C. Detection of Exudates

The Condition of the retina can be known from the color fundus image. The Appearance and location of different features such as exudates, hemorrhages and drusen in color fundus image are used for the assessment of diabetic retinopathy (DR). Exudates are the the early lesions of diabetic retinopathy so the automatic detection is very important to slow down the progression of retinopathy. Malaya Nath et al. [15] proposed a novel method for detecting the changes appeared in the color fundus image due to the progression of diabetics by using independent component analysis (ICA) on wavelet sub bands. The proposed method for the change detection consist of steps such as splitting to different color channels, preprocessing, wavelet decomposition, selection of sub band, formation of input matrix for ICA, and fast ICA. Seven level wavelet decomposition is performed to the preprocessed image by Daubechies-4 (db4) mother wavelet. Brigitta Nagy et al. [16] proposed an Ensemble based approach for exudates detection. In this method an optimal combination of preprocessing methods and exudates candidate extractors are found and organized into a voting system. An ensemble based system suggests that combination of individual algorithms built upon different principle tend to outperform individual accuracies. Simulated annealing-based search algorithm [17] is used to find out optimal ensemble out of the large number of the database.

Narsimhan et al. [18] have proposed the method for exudates detection involves first, the localization of optic disc followed by color histogram processing. The segmentation is done to detect the edges. The segmentation is achieved by finding the edges in the smoothened input image. Third, color histogram thresholding is used to detect exudates. Walter et al. [19] have detected exudates in the fundus image using morphological reconstruction and gray level transformation. Gardener et al. [20] proposed the neural networks based approach to locate exudates. The computational intelligence technique [21] and Fuzzy C-means clustering [22] were used for the exudates detection.

D. Detection of Microaneurysm

Micro aneurysm is nothing but small blow out swelling from the blood vessel. MA are saccular pouches caused due to the distension of capillary walls. They are the first clinical sign of retinopathy. MAs are appear like small circular dark (reddish) dot which are less than 125 µm in size.

Narsimhan et al. [18] proposed the method to detect MA involve morphological white top hat transformation to enhance and isolate the micro aneurysm. The top-hat transformed image is got by obtaining the difference between the input image and opened image. The structuring element is rotated in twelve different orientations in order to efficiently extract the small circular structures from the image. Lay et al. [23] also used the morphological opening with linear structuring element and using Top hat transform extracted the details which may corresponds to MA. To differentiate circular and linear micro aneurysms segment bilinear top hat transformation is used [24].Antal et al. [25] have proposed ensemble based method for the detection of MA. This is similar to an approach used by Brigitta Nagy et al. [16]. The difference lies in the preprocessing and candidate extracture method used by them. In this , first the system is trained based on the ground truth of the retinal images decided by clinical experts and then real time detection of MAs are carried on.

V. PROCESS OF EVALUATION

The diagnostic test is an examination used in classification of patients into a particular class or clinical state. There are four possible results for the test if the outcome of the examination is binary: true positive, true negative, false positive and false negative. For abnormal test subject, the result is true positive if diagnostic test outcome is abnormal and false negative if diagnostic test outcome is normal. For normal test subject, the result is true negative if diagnostic test outcome is normal and false positive if diagnostic test outcome is abnormal. For a given set of subjects, the number of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) can be used to determine the accuracy of the diagnostic test in form of sensitivity (SN) and specificity (SP). Performance of the test classifier can be measured in the form of sensitivity, specificity and positive predictive accuracy. True Positive (TP) is number of positives outcomes of the test, when compared with the reference of gold standard. This gives number of abnormal cases is correctly classified in the classifier & if the normal sample is classified as abnormal then it is called as False Positive (FP). If the normal is classified correctly then it is it is True Negative (TN). If the abnormal sample is classified as normal then is called as False Negative (FN).

$$Se = \frac{TP}{TP + FN} \tag{1}$$

$$Sp = \frac{TN}{TN + FP} \tag{2}$$

$$Ppv = \frac{TP}{TP + FP} \tag{3}$$

$$\text{Npv} = \frac{TN}{TP + FN} \qquad (4)$$

The sensitivity of a test is the probability that it will produce a true positive result when used for diseased population. A sensitivity of 100% means that the test recognizes all sick people as such. The receiver operating characteristic curve, also known as ROC analysis, is a widely used tool in medical community for visualizing and comparing methods based on their performance. It is a graphical representation that describes the trade-off between the sensitivity and specificity (e.g., correctly classified normal images vs. correctly classified abnormal images).The method was initially developed to evaluate the classification accuracy in differentiating signal from noise in signal detection. In recent years the methodology has been adopted to various research areas such as in computer vision. The ROC analysis is also an acknowledged methodology in medical research in accordance with medical decision making.

In a manner to evaluate the performance of algorithm on fundus image , the blood vessel segmentation result are compared to the the corresponding manual creation of vessel mask in which Vessel pixels are assigned to 1 and Nonvessel pixels are set to 0. Se and Sp is the measure of well classified vessel and nonvessel pixel. Ppv is the ratio of pixels classified as vessel pixel that are correctly classified. Npv is the ratio of pixels classified as background pixel that are correctly classified. Acc is a global measure providing the ratio of total well-classified pixels. This method is evaluated on the Drive database images.

VI. MICROANEURYSMS DETECTION

1% of data is saturated at low and high intensities of I_{VE}. This increases the contrast of the output image I_{AI}. In addition to this it will also enhance microaneurysms structure which were difficult to identify in the vessel enhance image. In order to evaluate the result of the microaneurysms detection in fundus image, one must know the ground truth of the diagnosis in that image. Since in the DRIVE and STARE database testing images provided have the manual creation of the vessel segmentation Therefore I cannot test my algorithm on these database. Because actual location of the microaneurysms is not mentioned in their database..

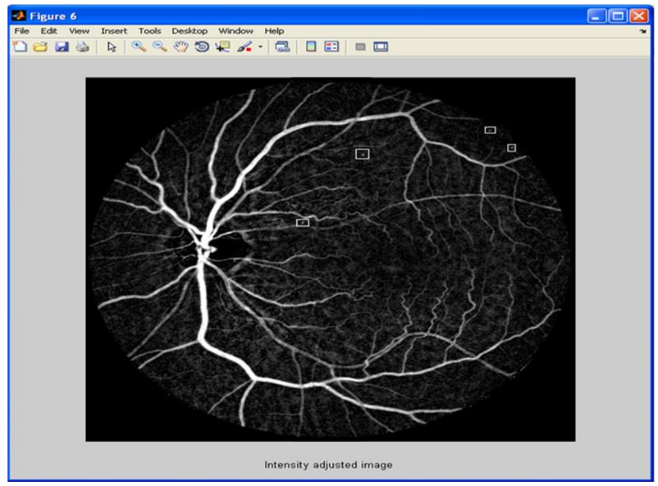

Fig.2. Intensity Adjusted Image

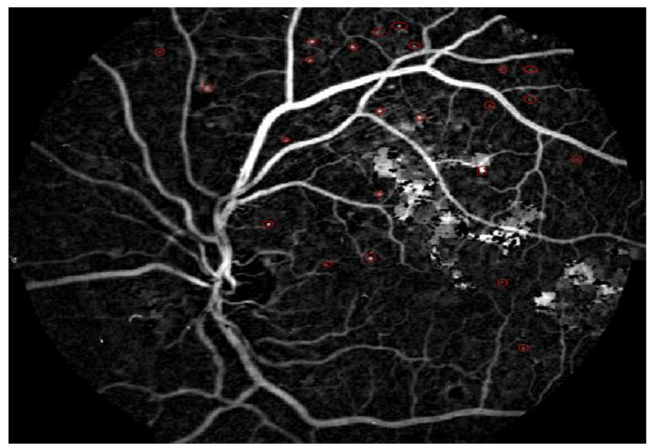

Fig. 3. Detection of Microaneurysms from Fundus Image

VII. CONCLUSION

Automated analysis of retinal images is an ongoing active field of research. There are large number of diabetic patients yet not screened are under the danger of vision degradation or loss. In this research work some of the simpler and some of the more recent analytical tools bought to analyse retinal images have been discussed. We have seen that standard image processing techniques that may be found in any good text on general image processing can go a long way to detecting certain features/lesions in retinal images and produce seemingly good results.

It is able to detect the microaneurysms from the fundus image without the need of doing fundus flourescene angiography and it is simple, flexible and robust. Vessel segmentation has been done using two pixel feature & appreciable accuracy is attained.

VII.REFERENCES

[1] http://www.tribuneindia.com/2012/20121115/dun.htm

[2] About diabetes: World Health Organization report, http://www.who.int/diabetes/facts/en/index.html/ accessed arch 31, 2009.

[3] Abràmoff MD, Niemeijer M, Suttorp - Schulten MSA, Viergever MA,Russell SR, van Ginneken B .Evaluation of a system for automatic detection of diabetic retinopathy from color fundus photographs in a large population of patients with diabetes. Diabetes Care. 2008;31(2):193–198.

[4] Geoff Doughorty, "Medical Image Processing", Chapter 11, Image Analysis of Retinal Images, Michael J. Cree and Herbert F. Jelinek.

[5] Deepika Vallabha 0, Dorairaj R, Namuduri K, Thompson H,"Automated Detection and Classification of Vascular Abnormalities in Diabetic Retinopathy"

[6] A. Hoover, Kouznetsoza, V., Goldbaum, M. (2000) "Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response." IEEE Transactions on Medical Imaging, 19, 203-210.

[7] Diego Marín, Arturo Aquino*, Manuel Emilio Gegúndez-Arias, and José Manuel Bravo, " A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray-Level and Moment Invariants-Based Features", IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 30, NO. 1, JANUARY 2011

[8] M. AI-Rawi, H. Karajeh, Genetic algorithm matched filter optimization for automated detection of blood vessels from digital retinal images, Comput. Methods Programs Biomed. (2007).

[9] J.P. Antoine, P . Carette, R . Murenzi ,a nd B. Piette,"Image analysis with two-dimensional continuous wavelet transform", Signal Processing, vol. 31, no. 3,241-272, 1993.

[10] Hipwell, J., Strachan, F., Olson ,J., McHard y, K. Sharp, P. Forrester, J, 2000. Automated detection of Microaneurysms in digital red-free photographs: a diabetic retinopathy screening tool. Diabet. Med. 17,588-594.

[11] Sinthanayothin,C.,Boyce,J., Williamson, T.,Cook, H.,Mensah , E.,LaI,S.,Usher,D.,2002. Automated detection of diabetic retinopathy on digital fundus images. Diabet. Med. 19,105- 1 12.

[12] M. Usman Akram, Ibaa Jamal, Anam Tariq and Junaid Imtiaz, "Automated Segmentation of Blood Vessels for Detection of Proliferative Diabetic Retinopathy", Proceedings of the IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI 2012) Hong Kong and Shenzhen, China, 2-7 Jan 2012.

[13] A. Tariq and M. U. Akram, "An Automated System for Colored Retinal Image Background and Noise Segmentation", IEEE Symposium on Industrial Electronics and Applications (ISIEA 2010), pp. 405-409, Oct. 2010.

[14] J.P. Antoine, P . Carette, R . Murenzi, a nd B. Piette, "Image analysis with two-dimensional continuous wavelet transform", Signal Processing, vol. 31, no. 3,241-272, 1993.

[15] Malaya Kumar Nath, and Samarendra Dandapat, "Detection of Changes in Color Fundus Images due to Diabetic Retinopathy", CISP2012|Proceedings|81.

[16] Brigitta Nagy, Balint Antal, Balazs Harangi, Andras Hajdu, "Ensemble-based exudate detection in color fundus Images", 7th International Symposium on Image and Signal Processing and Analysis (ISPA 2011) September 4-6, 2011, Dubrovnik, Croatia.

[17] S. Kirkpatrick, C. D. Gelatt, andM. P. Vecchi, "Optimization by simulated annealing," Science, vol. 220, pp. 671–680, 1983.

[18] K.Narasimhan, V.C.Neha, K.Vijayarekha, "An Efficient Automated System for Detection of Diabetic Retinopathy from Fundus Images Using Support Vector Machine and Bayesian Classifiers", 2012 International Conference on Computing, Electronics and Electrical Technologies [ICCEET]

[19] Walter T, Massin P, Erginay A, Ordonez R, Jeulin C, Klein J-C, "Automatic Detection of Micro aneurysms in Color Fundus Images Medical Image analysis"2007.

[20] Gardner,G.,Keating,D.,Williamson,T.,Elliott,A.,1996. Automated detection of diabetic retinopathy using an artificial neural network: a screening tool. Br. J. Ophthalmol. 86,940- 944.

[21] Osareh,A., Mirmedhi,M.,Thomas, B., Markham,R., 2003.Automated identification of diabetic retinal exudates in digital colour imaging. Br. J. Ophthalmol. 87, 1220 – 1223.

[22] Bezdek,J.,Pal,M.,Keller,1.,Krisnapuram , R.,1999. Fuzzy Model and Algorithms for Pattern Recognition and Image Processing. Kluwer Academic Press,London

[23] Lay,B.,Baudoin, C.,Klein,J.-C., 1983. Automatic detection of micro aneurysms in retinopathy fluoro-angiogram. Proc. SPIE 432,165.

[24] Spencer T .OIson,J.,McHardy,K., Sharp, P.,Forrester, 1.,1996. An image-processing strategy for the segmentation and quantification of microaneurysms in fluorescein angiograms of the ocular fundus. Comput. Biomed. Res. 29,284--302.

[25] Balint Antal, Andras Hajdu, "An Ensemble-Based System for Microaneurysm Detection and Diabetic Retinopathy Grading", IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 59, NO. 6, JUNE 2012

[26] Diego Marín, Arturo Aquino*, Manuel Emilio Gegúndez-Arias, and José Manuel Bravo, "A New Supervised Method for Blood Vessel Segmentation in Retinal Images by Using Gray-Level and Moment Invariants-Based Features", IEEE Transactions on Medical Imaging, Vol. 30, No. 1, JANUARY 2011.

[27] S. Chaudhuri, S. Chatterjee, N. Katz, M. Nelson, and M. Goldbaum, "Detection of blood vessels in retinal images using two-dimensional matched filters," IEEE Trans. Med. Imag., vol. 8, no. 3, pp. 263–269, Sep. 1989.

[28] X. Jiang and D. Mojon, "Adaptive local thresholding by verification based multithreshold probing with application to vessel detection in retinal images," IEEE Trans. Pattern Anal. Mach. Intell., vol. 25, no. 1,pp. 131–137, Jan. 2003.

[29] M. E. Martinez-Perez, A. D. Hughes, S. A. Thom, A. A. Bharath, and K. H. Parker, "Segmentation of blood vessels from red-free and fluorescein retinal images," Med. Imag. Anal., vol. 11, pp. 47–61, 2007.

[30] M. G. Cinsdikici and D. Aydin, "Detection of blood vessels in Ophthalmoscope images using MF/ant (matched filter/ant colony) algorithm,"Comput. Methods Programs Biomed., vol. 96, pp. 85–95, 2009.