Graph Representation of Vessel Tree and A/V Classification Method for AVR Calculation On Retinal Images

Minakshee K. Chandankhede, Prof. Leena H. Patil

***Abstract*— The estimation of Arteriolar-to-Vennular Diameter Ratio is also an important phase in diagnosing various vascular diseases like Diabetic retinopathy etc. Humans Retinal vessels are divided into two types they are arteries and veins. For the diagnosis of various diseases it is an essential to differentiate the vessels into arteries and veins. Even the abnormal size of the ratio of diameter of arteries with respect to veins also be an indicator of various retinal diseases. This paper presents an graph based approach for Arteriolar-to-vennular Diameter Ratio (AVR) calculation based on the classification of retinal blood vessels. The proposed method classifies the entire retinal vascular tree deciding on the type of graph nodes that is each intersection point and vessel segment between them that is graph links. Classification of a vessel segment as A/V is performed through the combination of the graph-based labeling results with a set of width features. The results of this proposed method are tested on the images of the well known DRIVE database which gives the accuracy of 97.5%. Hence our proposed method is beneficial for the diagnosis of diabetic retinopathy by estimating the AVR values.**

***Keywords*- AVR, Histogram Equalization, Graph, Arteries, Veins.**

I. Introduction

Diabetic retinopathy is a disease caused by complications of diabetes, which can eventually results to blindness. It is an advanced step of diabetes, a systemic disease, which affects up to 80 percent of all patients who have had diabetes for 10 years or more. From the observation taken from the result statistics, research indicates that at least 90% of these new cases could be reduced if there were proper and vigilant treatment and monitoring of the eyes routinaly. The longer a person has diabetes, the higher his or her chances of developing diabetic retinopathy. In each year in the United States, diabetic retinopathy accounts for 12% of all new cases of blindness. It is found that it is also the leading cause of blindness for people aged 20 to 65 years.

Retinal images [2] of humans play an important role in the detection and diagnosis of many eye diseases for ophthalmologists. Some diseases such as diabetic retinopathy, macular degeneration and glaucoma are very dangerous for they can lead to blindness if they are not detected in time and correctly. Therefore, the detection for retinal images is necessary, and among them the detection of blood vessels is most important. The alterations about blood vessels, such as length, width and branching pattern, can not only provide information on pathological changes but can also help to grade diseases severity or automatically diagnose the diseases. Detection of various diseases in eye fundus [1] images have using digital image analysis methods has large potential benefits, which allowing examination of large number of fundus images is very less time and at lower cost. Blood vessels show abnormalities at early stages also blood vessel alterations. Generalized arteriolar and venular narrowing which is related to the higher blood pressure levels, which is generally expressed by the Arteriolar-to-Venular diameter ratio [11].

The AVR value can be an indicator of other diseases like Diabetic retinopathy and retinopathy of prematurity. For the estimation of AVR it is essential to classify the blood vessels that are arteries and veins, since slight classification errors in the vessels can have large influence on the final value. AVR can be comprised of two elements they are Central Retinal Arteriolar Equivalent (CRAE) and Central Retinal Venular Equivalent (CRVE). The Central Retinal Arteriolar Equivalent (CRAE), Central Retinal Venular Equivalent (CRVE) are useful in finding the abnormality in blood vessels. It also beneficial in taking the follow-up of some systemic diseases, namely diabetes, hypertension and other vascular disorders. These diseases even change the vessel branching pattern, so there is the need to make the measurement of bifurcation and other geometrical features such as crossing points, meeting points etc. However, manual detection of blood vessels is much more difficult since the blood vessels in a retinal image are complex and with low contrast. Also, there are usually numbers of retinal images to detect a disease. Hence, it manually measurement becomes tiresome. As a result, reliable and automatic methods for extracting and measuring the vessels in retinal images are needed. Here graph representation [11] can be shown with the bifurcations, crossing points and meeting points of the vessels that are classified into arteries and veins. The main goal of this paper is estimation of the average diameter ratio of the arteries with respect to veins, which is the strong parameter in the diagnosis of the various vascular diseases.

***Manuscript received May, 2015*.**

***Minakshee K. Chandankhedee**, Computer Science and Engineering, Priyadashini Institute of Engineering and Technology, RTMNU Nagpur, India,*
,

***Prof. Leena H. Patil**, Computer Science and Engineering, Priyadarshini Institute of Engineering and Technology, RTMNU Nagpur, India.*

II. LITERATURE REVIEW

This section describes the comprehensive review of the existing techniques, algorithms and methods related to classification of vessels, which provides the diagnosis of the various retinal diseases. Classifying retinal vessels into arteries and veins using image features and a classifier. A set of centerline features is extracted and a soft label is assigned to each centerline, indicating the likelihood of its being a vein pixel. Then the average of the soft labels of connected centerline pixels is assigned to each centerline pixel. They tested different classifiers and found that the *k*-nearest neighbor (kNN) classifier provides the best overall performance. In [18], the classification method was enhanced as a step in calculating the AVR value. For the estimation of AVR there various methods are present in the literature they are as follows.

In the Computer-aided Diagnosis System for the Assessment of Retinal Vascular Changes Behdad gives an automatic method which gives an idea regarding various functionalities, such as vessel segmentation [23], vessel registration, vessel width estimation, vessel classification into artery/vein and also the optic disc segmentation etc. Here in this concentrate on two parameters, namely the Central Retinal Arteriolar Equivalent (CRAE), Central Retinal Venular Equivalent (CRVE) which are the components of Arteriolar-to-Venular Ratio, also gives various geometrical features associated with vessel bifurcations, vessel crossing points etc regarding the vessels.

In Automated detection and classification of major retinal vessels for determination of diameter ratio of arteries and veins. [13] Here firstly detect the major retinal vessels and classify them into arteries and veins for the estimation of AVR ratio. Here starting with the retinal vessel segmentation provided on the images in the database, here arteries and veins each in the upper and lower temporal regions were first selected manually for establishing the gold standard. Then applied the black top-hat transformation and double-ring filter to extract the retinal blood vessels from the original color image. From the extracted vessels, then the large vessels extending from the optic disc to temporal regions were first selected as target vessels for calculation of AVR. Then the Image features were extracted from the vessel segments that will get after segmentation from the edge of optic discs. After that the target vessel segments in the training cases were classified into arteries and veins by using the linear discriminate analysis.

In Arteriolar-to-venular diameter ratio estimation-A pixel-parallel approach [14] used a methodology to extract the retinal vessel tree [23], which will be tested in a fine-grain pixel-parallel processor array, is used for the estimation of the AVR ratio in angiographies. In Vivo Assessment of Retinal Vascular Wall Dimensions. [15] Here used a transgenic mouse model to quantify AVR in vivo based on total vessel dimensions. In Assessment of vascular changes in retinal images [16] gives an automatic approach for the estimation of the AVR in retinal images. It explains the method includes vessel segmentation, , optic disc detection, vessel caliber estimation, region of interest determination, classification of vessels and finally AVR calculation.

In Hypertensive Retinopathy Diagnosis from Fundus Images by Estimation of AVR [17] has proposed an algorithm in which first step having initially the blood vessels are segmented out from the pre processed retinal grayscale images. Then the features of Gray level and moment were extracted to classify the resulted pixels belongs to the blood vessel class or not should be decided. Variations in the intensity of the pixel and alterations in color information is considered to classify the retinal blood vessel into arteries and veins. To measure the arteriolar-to-venular ratio first estimates the vessel width method which is useful for diagnosing the early stages of the hypertension.

In An improved system for the automatic estimation of the Arteriolar-to-Venular diameter Ratio (AVR) in retinal images [18] gives an enhanced system to calculate the AVR value that is Arteriolar-to-Venular Diameter Ratio by automatically. First of all enhanced the Retinal image to highlight the vessel network, and then the vessels should be traced by the vessel tracking algorithm. After getting the vessel structure, the position of the optic disc was find out on the basis of that the AVR value to be calculated. After that blood vessels get classified into arteries and veins, even the caliber also computed fro that easily estimate the AVR value. Some improvements were needed in the post-processing algorithms to enhance vessel tracking method and gives a new artery/vein classification technique.

In an Automatic Estimation of the Arteriolar-to-Venular Diameter Ratio (AVR) in retinal images [19] here developed a computerized system to estimate AVR value automatically. Here original image were enhanced by ant enhancing method like histogram equalization. Extracted vessels then traced by a vessel tracking algorithm. From the detected vessel structure, the position of the optic disc is derived and find out the region where AVR is calculated. Blood vessels within this region are classified into arteries or veins, and also the caliber were estimated and finally the AVR parameter is computed.

In Automated selection of major arteries and veins for measurement of arteriolar-to-venular diameter ratio on retinal fundus images [20] here present an automatic method for measurement of arteriolar-to-venular diameter ratio (AVR). The method includes the segmentation of the optic disc for the determination of the AVR value. Retinal vessel segmentation, vessel classification into arteries and veins, selection of major vessel pairs, and measurement of AVR value can be calculated. This method gives the objective calculation of AVR value.

III. PROPOSED METHOD

Diabetic retinal [22] diseases refer to a group of retinal problems that occurs due to the complications due to blockage of arteries and veins. This can cause several retinal diseases and may be person get vision less. It is caused by alterations in the blood vessels of the retina. The human retina is the light-sensitive tissue at the back of the eye [12] . A healthy retina is necessary for good vision to see. If you have diabetic retinopathy [21], at first you may not notice changes or alterations to your vision. But over time, diabetic retinopathy can get worse and cause vision loss or blindness. Proposed system have mainly four steps. They are as follows.

1) Vessel Extraction and Segmentation.

2) Graph Extraction and Generation.

3) A/V Classification.

4) AVR Calculation.

Here we take retinal color image from the well known DRIVE dataset which is publically available. But for the processing these retinal images are first converted into Grayscale image, As we know the computational speed of it is more than color image. In some cases vessels of retinal image do not clear to see. Hence there is the need of enhancement. Here retinal image is enhanced by the Histogram Equalization method. Then the vessels of the retinal image are extracted [10]. In the recent years graph have emerged as a unified representation and graph method have used in retinal image segmentation, retinal image classification and retinal image registration. Hence proposed method takes the approach of graph based classification. The Block Diagram for Proposed method are as follows.

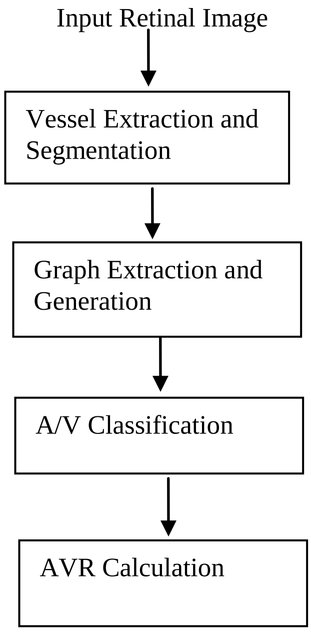

Fig. 1 Block Diagram of Proposed work.

The proposed method uses the following step: Image Enhancement, Grayscale conversion, Image binarization, Morphological operation, Graph Generation, Feature extraction, A/V Classification and AVR Calculation.

A. Image Enhancement

Histogram Equalization [1] is frequently used to increase the global contrast [9] of the images, particularly the data that accompanied by the image is represented by close contrast values. Because of its modification the intensities can be better distributed on the histogram of the image. Hence this allows for areas of the local contrast which is low to enhance up to a higher contrast. A basic advantage of the method is that it is a fairly clear-cut technique and it is an invertible operator. Suppose if we know the histogram equalization function then we can easily recovered the original histogram. Here we take the retinal image for the work. In some cases the retinal image will not show the clear vessels. So our first aim is to enhance that image by using the method of histogram equalization. Here this method construct the finer image having mostly all the vessels for the diagnosis. For enhancing the contrast of the retinal image by histogram equalization it can be done by proficiently thinning out the most recurrent & common intensity values. This method is basically useful for the images with backgrounds and foregrounds that is objects that are both bright or both dark.

B. Grayscale Conversion

In the grayscale [2] conversion RGB that is color image is converted into grayscale image. To convert the RGB image to its grayscale image, firstly it is require calculating the values of its red, green, and blue color intensities. If the output Gray image is IR and the red, green, and blue components are R, G, and B, respectively, then The intensity gradient between the foregrounds is relatively low with its background. To choose an accurate threshold value for differentiating blood vessels it is a difficult task. Hence, edge enhancement or pre-processing of the image for subsequent analysis turns out to be more essential.

C. Image Binarization

Image binarization [5] is a process that converts an image of up to 256 gray levels to a black and white image. Frequently, binarization is used as a pre-processing step. The easiest way to use image binarization is by choosing a threshold value, and classifies all pixels with values above this threshold as white, and all other less than threshold pixels as black. But the problem is how to select the correct threshold. Binary images are produced from color images by segmentation process. Here segmentation is the process of assigning each pixel in the source image to two or more classes. If there are more than two classes then the usual result is several binary images.

D. Morphological Operation

Morphological operations [4] mostly used for the Segmentation of the retinal image. Basically the method of segmentation divides an image into its sub constituent regions or parts. Segmentation is carried out up to the level to which the problem being solved that is the abnormality has found. The morphological operators can be used simply to detect edges of the retinal blood vessels, but only morphological operation do not sufficient to extract the exact body of all retinal blood vessel structure. Therefore, retinal blood vessel extraction [5] is an important parameter to investigate the desired information. The edges of the particular image describe object boundaries after that they are useful for the image segmentation, image registration, and classification of the objects in a given work. An edge is distinct by a discontinuity in gray level values of the image. Hence an edge is the boundary between an object and the background in the image. Edge detection is an active research area as most research work uses it. Along with the morphological operator [3] canny edge detection is used in this paper for the vessel detection from the retinal image. In the literature, there are a lot of edge detection techniques are used like Sobel, Prewitt [7], Marr-Hildereth, Roberts, Robinson etc.

E. Centerline Extraction

Then retinal vessels extracted by morphological operation and canny edge detection method will be thinned by using Morphological Thinning [11]. Morphological Thinning process is a morphological operation [4] that consecutively erodes away the foreground pixels until they are one pixel wide. In this algorithm a standard thinning algorithm is employed, that performs the thinning operation using two sub iterations. This algorithm is easily available in MATLAB using the thin operation under the bimorph function. Each sub iteration will start by examining the neighboring pixel in the binary image, and based on a particular set of pixel-deletion criteria, it checks whether the pixel can be deleted or not. These sub iterations continue until no more pixels can be deleted. The application of the thinning algorithm to a retinal image preserves the connectivity of the ridge structures while forming a skeletonized version of the binary image. This skeleton image is then used in the subsequent extraction of minutiae.

F. Graph Generation

A graph [11] is a representation of the vascular network, where each node denotes an intersection point in the vascular tree, and each link corresponds to a vessel segment between two intersection points. For generating the graph, we have used Minutiae Extraction method. The nodes are extracted from the centerline image by finding the bifurcation points which are detected by considering pixels with more than two neighbors and the endpoints or terminal points by pixels having just one neighbor. In order to find the links between nodes (vessel segments), all the bifurcation points [11] and their neighbors are removed from the centerline image and as result we get an image with separate components which are the vessel segments.. On the other hand, any given link can only connect two . Here bifurcation points and terminal points are marked by blue and red color respectively.

G. Feature Extraction

Feature extraction [6] is used to reduce the dimensionality and considering the interesting parts of an image as a set features called as feature vector. This approach is more useful when the image sizes are large and using lot of memory then it is required to extract features to quickly complete tasks such as image matching and retrieval. Here common feature extraction techniques include Histogram of Oriented Gradients, Speeded Up Robust Features, Local Binary Patterns, Haar wavelets, and color histograms etc. So we can say transforming the input data into the set of features is called feature extraction. Feature extraction involves simplifying and resolving the amount of resources needed to represent a large set of data accurately. Here in the proposed method the input data should be transformed into a reduced representation of set of features such as Intensity, Area, Perimeter, Centroid and Diameter. Here diameter is the important feature to classify the retinal blood vessels. These features are extracted by using the region properties for retinal image. These features are explained below.

- Area: The actual number of pixels in the region.
- Centroid: 1-by-Q vector that specifies the center of mass
- Diameter: Scalar that specifies the diameter of a circle with the same area as the region. Computed as sqrt (4*Area/pi).

H. A/V Classification

Here automatic graph based approach is used for classifying retinal vessels into arteries and veins . The features gets extracted on the basis of centerline extracted image and a label is assigned to each centerline, indicating the artery and vein pixel. Based on these labelling phase, the final goal is now to assign one of the labels with the artery class (A), and the other with vein class (V). In order to allow the final classification between A/V [24] classes along with vessel intensity information the structural information and are also used. Classification is done with the help of SVM classifier. In the recent years, SVM [25] classifiers have demonstrated excellent performance in a variety of pattern recognition problems. The input space is mapped into a high dimensional feature space. Then, the hyper plane that maximizes the margin of separation between classes is constructed. The points that lie closest to the decision surface are called *support* vectors directly affect its location. When the classes are non-separable, the optimal hyper plane is the one that minimizes the probability of classification error.Initially input image is formulated in feature vectors. Then these feature vectors mapped with the help of kernel function in the feature space. And finally division is computed in the feature space to seperate out the classes for training data. A global hyper plane is sought by the SVM in order to separate both the classes of examples in training set and avoid over fitting. This phenomenon of SVM is more superior in comparison to other machine learning techniques which are based on artificial intelligence. Here the important feature for the classification is the width of the vessels. With the help of SVM classifier we can easily seperate out the vessels into arteries and veins.

I. AVR Calculation

The AVR was first suggested as a good parameter to investigate retinal vascular geometry by Stokoe and Turner (1966). It was developed as a general measure of the ratio between the average diameters of the arterioles with respect to the venules. It is comprised of two components, the central retinal artery equivalent (CRAE) and the central retinal vein equivalent (CRVE),expressed as a quotient.

IV. RESULT AND DISCUSSION

The proposed A/V Classification and AVR calculation with Support Vector Machine (SVM) was done using MATLAB. Color RGB retinal image from DRIVE database is given as the input. Vessel Extraction is done by using morphological operation and canny edge detection method. Grayscale conversion is used to choose an accurate threshold value and for detecting edges. Binarization is used to achieve the gray level thresholding with the change in variation to show 1 as white and 0 as black. Morphological operation is necessary for segmentation to extract exact body of the vascular network along with the help of canny edge detection. After vessel detection by applying region properties different features are extracted. The features which are extracted are Intensity, Area, Centroid, Intensity, Perimeter and Diameter. A/V classification is done with the help of SVM classifier. SVM is trained to detect whether the retinal image is abnormal or normal. The proposed method has been verified by taking 40 images from well known DRIVE database to detect the retinal blood vessel.

Fig .a

Fig. b

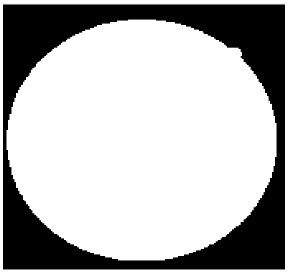

Fig. c

Fig. d

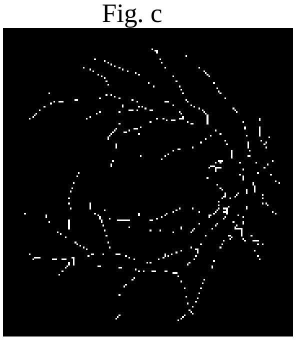

Fig. e

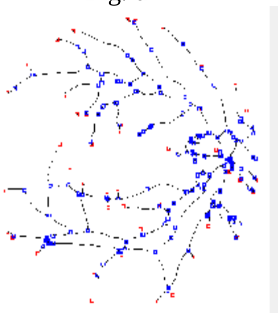

Fig. f

Fig 2. a) RGB Retinal Image b) Grayscale Image c) Binary Image d) Extracted Vessels e) Centerline Extraction f) Generated Graph

The proposed method performs best by segmenting even smaller blood vessels. All the work is done using MATLAB.And finally the performance is verified by evaluating the values of True Positive, False Positive, False Negative and True Negative.

$$\text{Sensitivity (Se)} = TP/(TP + FN)$$

$$\text{Specificity (Sp)} = TN/(TN + FP)$$

$$\text{Accuracy (Acc)} = (TP + TN)/(TP + FN + TN + FP)$$

Here sensitivity is defined as the ratio of the number of TP with respect to the sum of the total number of TP plus FN. The value of sensitivity always lies between 0 and 1. While Specificity is defined as the ratio of the number of TN with respect to the sum of the total number of FP plus TN. Even the value of specificity lies between 0 and 1.Here the two parameter sensitivity and specificity are calculated with respect to ground truth images available in the DRIVE dataset. The value of Se and Sp must be high for better retinal blood vessel segmentation results. Here TP is true positive refers to the correctly detected blood vessels, TN that is true negative refers to the wrongly detected blood vessels, and FP-false positive and FN-false negative refer to the correctly and wrongly detected blood vessel pixels.

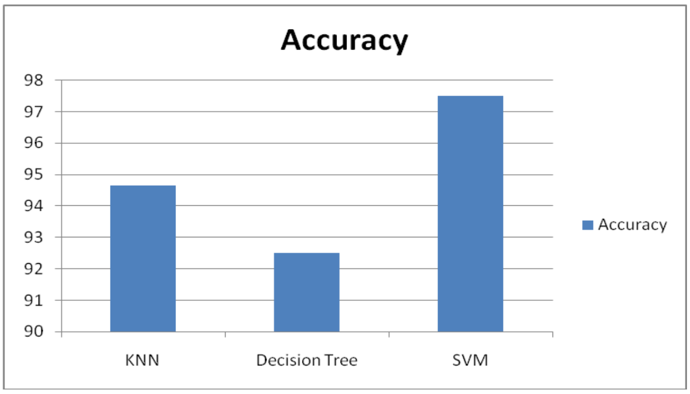

Fig. 3. Comparative Accuracy Analysis

We have compared our proposed method result with Decision Tree and KNN classifier. Accuracy for KNN is 94.66%, for Decision Tree is 92.5 and for Proposed method SVM is 97.5%. Accuracy of correctly classified retinal vessels with proposed method are compared with Decision Tree and KNN as follows.

V. CONCLUSION

The automatic estimation of AVR for retinal blood vessels has been proposed in this paper. The segmentation of retinal blood vessels was essential for classifications and diagnosis of retinal image that is normal or abnormal. This paper proposed a methodology which gives graph based approach to classify the vessels and estimate the AVR. The performance of the proposed methodology was analyzed with respect to ground truth images with publicly available DRIVE dataset, consisting of normal and abnormal images. The proposed system methodology is achieved the average vessel classification accuracy of 97.50% in DRIVE dataset with their corresponding ground truth images. Hence our proposed method successfully estimate the AVR that is the Arteriolar-to-Vennular Diameter Ratio for the diagnosis of diabetic retinopathy.

ACKNOWLEDGMENT

I sincerely acknowledge the teaching staffs of the department and authors of DRIVE database for making their retinal image databases publicly available.

REFERENCES

[1] Priyanka Yadao, Sayali Naval, Animesh Maheshwari, “Blood Vessel Segmentation in Retinal Fundus Images using Matched Filter”, Journal of Harmonized Reaserch in Engineering, 2014.

[2] R. Keerthikanth, A. Rajan, “Detection of Retinal Blood Vessels using Curve let Transform” ,ICSEC, Vol. 2, Issue 3, May 2014.

[3] K. Gayathri, D. Narmada, K. Thilagavathi, K. Pavithra and M. Pradeepa, “Detection of Dark Lesions from Coloured Retinal Image using Curvelet Transform and Morphological Operation”, IJNTEC-ISSN:2347-7334,Vol. 2,Issue 3,May 2014.

[4] M. Kavitha, Dr. S. Palani, “A New Fast Curvelet Transform with Morphological Operations based method for Extraction of Retinal blood vessels using Graphical User Interface”, International

Journal of Scientific & Engineering Research, Volume 3, Issue 6, June-2012.

[5] Nidhal Khadhair El Abbadi, Enas Hamood Al Saadi, "Blood Vessel Extraction Using mathematical morphology", Journal of Computer Science 9(10): 1389-1395, 2013.

[6] Shradha Mirajkar, M. M. Patil, "Feature Extraction Of Diabetic Retinopathy Images", International Journal of Computer Applications Proceedings on Emerging Trends in Electronics and Telecommunication Engineering, 2013.

[7] H.S. Bhadauria1, S.S. Bisht2, Annapurna Singh, "Vessels Extraction from Retinal Images", IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735. Volume 6, Issue 3, May. - Jun. 2013

[8] Yong Yang , Shuying Huang , Nini Rao , "An Automatic Hybrid Method For Retinal Blood Vessel Extraction", Int. J. Appl. Math. Computer. Sci., Vol. 18, No. 3, 399–407, 2008.

[9] R.Radha1 and Bijee Lakshman, "Retinal Image Analysis Using Morphological Process And Clustering Technique", Signal & Image Processing : An International Journal (SIPIJ) Vol.4, No.6, December 2013.

[10] V. Vijaya Kumari 1, Dr. N. Suriyanarayanan, " Blood Vessel Extraction Using Wiener Filter and Morphological Operation", International Journal of Computer Science & Emerging Technologies (E-ISSN: 2044-6004) 7 Volume 1, Issue 4, December 2010.

[11] Behdad Dashtbozorg, Ana Maria Mendonça, Aurélio Campilho, "An Automatic Graph-Based Approach for Artery/Vein Classification in Retinal Images", IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 23, NO. 3, MARCH 2014.

[12] Rana Uday Singh1 Prof. Gulshan Goyal Segmentation Based Vessel Extraction of Retina",International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 5, May 2013.

[13] Chisako Muramatsu , Yuji Hatanaka , Tatsuhiko Iwasea , Takeshi Haraa , Hiroshi Fujitaa, "Automated detection and classification of major retinal vessels for determination of diameter ratio of arteries and veins" Medical Imaging 2010: Computer-Aided Diagnosis, edited by Nico Karssemeijer, Ronald M. Summers, Proc. of SPIE Vol. 7624, 76240J ,2010

[14] C.Alonso_montes, M.G. Penedo, D.L. Vilarino, " Arteriolar-to-venular diameter ratio estimation: A pixel-parallel approach", 11th International Workshop on Cellular Neural Network and their Applications,2008

[15] Fischer MD, Huber G, Feng Y, Tanimoto N, Mühlfriedel R, Beck SC, Tröger E, Kemstock C Preising MN, Lorenz B, Hammes HP, Seeliger MW, " In vivo assessment of retinal vascular wall dimensions", Invest Ophthalmol Vis Sci.,2010.

[16] Dashtbozorg, B. ; INEB-Inst. de Eng. Biomed., Univ. do Porto, Porto, Portugal ; Mendonca, A.M. ; Campilho, A, " Assessment of vascular changes in retinal images", 2014 IEEE International Symposium on Medical Measurement and Applications, 2014.

[17] K. Vijayarekha, K. Narasimhan, V.C. Neha, "Hypertensive Retinopathy Diagnosis from Fundus Images by Estimation of Avr", International Conference On Modelling Optimization And Computing, 2012.

[18] Tramontam L, Grisan E , Ruggeri A, "An improved system for the automatic estimation of the Arteriolar-to-Venular diameter Ratio (AVR) in retinal images", 30th Annual International Conference of the IEEE Engineering in Medicine and Biological Society, 2008.

[19] A.Ruggeril Tramontan and E. Grisan,"Automatic estimation of the arteriolar-to-venular diameter ratio (AVR) in retinal images", Acta Ophthalmologica vol 86, 2008.

[20] Chisako Muramatsua,, Yuji Hatanaka , Tatsuhiko Iwasea,, Takeshi Haraa,, Hiroshi Fujitaa, "Automated selection of major arteries and veins for measurement of arteriolar-to-venular diameter ratio on retinal fundus images", Computerized Medical Imaging and Graphics 35, 2011.

[21] C.A.Sathiyamoorthy,Dr.G.Kulanthaivel,"Classifying normality, abnormality of Diabetic retinopathy fundus images by Detecting and analyzing the od and vascular", Journal of Theoretical and Applied Information Technology,Vol.65 No.1,2014

[22] A.Osareh, And B. Shadgar, "Automatic Blood Vessel Segmentation in Color images of retina", Iranian Journal of Science & Technology, Transaction B Engineering, Vol. 33, No. B2, pp 191-206,2009

[23] D. Siva Sundhara Raja1 and S. Vasuki, "Automatic Detection of Blood Vessels in Retinal Images for Diabetic Retinopathy Diagnosis", Computational and Mathematical Methods in Medicine, 2014

[24] Joshi VS, Reinhardt JM, Garvin MK, Abramoff MD," Automated Method for Identification and Artery-Venous Classification of Vessel Trees in Retinal Vessel Networks", PLoS ONE 9(2): e88061. doi:10.1371/journal.pone.0088061

[25] Bibin. s, Manikandan. T," Blood Vessel Detection from Fundus Image for Diabetic Retinopathy Patients using SVM", International Journal of Engineering Research & Technology, ISSN: 2278-0181,Vol 3 Issue5,May 2014

