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Mathematical Morphology and Optimum Principal Curvature Based Segmentation of Blood Vessels in Human Retinal Fundus Images

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***Abstract:** The retinal abnormalities and diagnosis of Diabetic Retinopathy (DR), Glaucoma are accomplished by extraction of vessel network in human retinal images. An accurate segmentation is required for the pathological analysis. Various researchers proposed many automated systems for vessel segmentation, still this process needs an improvement due to the presence of abnormalities, different magnitude, dimension of the vessels, non-uniform lighting and variable structure of the retina. The proposed work is a new method for retinal vessel segmentation, which consists of three phases, (i) The vessels network is enhanced by using Contrast Limited Adaptive Histogram Equalization(CLAHE) and Median filtering techniques (ii) the smoothened image is segmented based on mathematical morphology and maximum principal curvature followed by cleaning operation to remove the small objects, (iii) the segmented image is compared with hand labeled Ground Truth image and is evaluated with the True Positive, False Positive , True Negative and False Negative parameters. The performance of this work is tested with the images existing in DRIVE database. This work achieves 0.965 Accuracy, 0.752 Sensitivity and 0.989 Specificity.*

Index Terms: : Diabetic Retinopathy, Mathematical Morphology, Maximum Principal Curvature

I.INTRODUCTION

The quantity of digital images are increasing day by day, which provides many research ideas for researchers in the computer vision field [1]. Segmenting the image into constituent regions named as Image segmentation, this is an important step to response various computer vision problems and the results of many of these complications rely on the quality of the segmentation. The main focus of medical informatics is to integrate computer technology with medical analysis, diagnosis and treatment [2]

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Image segmentation is therefore an important research topic that has attracted main researcher's attention during the past few years leading to many new approaches towards segmentation [3]. The main focus of segmentation is to partition the image into a many different region and locate objects and boundaries which further simplify examination of the image more efficiently. It helps in identifying the similar pixels of the image with respect to some feature such as colour, shape, intensity or texture. Image Segmentation includes various practical applications such as Medical image analysis and diagnosis, Anatomical structure, tracing the objects in satellite images, facial recognition, fingerprint recognition, traffic control systems, image retrieval, image annotation and object recognition [4]

The ophthalmologist can detect and diagnosis various eye diseases using retinal images. The Automated blood vessel segmentation process predict many eye diseases like hypertension retinopathy, Diabetic Retinopathy (DR), retinopathy of prematurity or glaucoma based on the feature extraction. The latest report states that there will be an epidemic rise of 4.4% in the global prevalence of diabetes [6]. Diabetic Retinopathy (DR) is a key factor of eye disease that occurs due to the existence of diabetes mellitus, and it leads to blindness. During the screening process, the retinal fundus images are taken for identifying DR. The presence of Hard Exudates (HE) and Microaneurysm (MA) in retinal image is the primary detection of DR. The early diagnosis of DR is required for constant monitoring of diabetic patient for treatment. Many methods have proposed by the researchers for retinal vessel segmentation by using different databases like STARE, DRIVE, CHASE_DBI.

II. RELATED WORKS

Sohini Roychowdry et al[7] applied high pass filtering technique to produces the two binary image followed by morphological reconstruction method. The general area of two binary images are identified as blood vessels. A group of eight features are extracted using Gaussian mixture model (GMM) from the binary images with the neighbourhood gradient values. The final process linked the major vessels with classified vessel pixel. The morphological process generates the structuring element to filter the required object from the background.

Jyotiprava Dash et.al [8], presents three phases for retinal vessel segmentation: the pre-processing phase uses the CLAHE technique to enhances the retinal images and followed by median filter, the second phase extract the blood vessel using mean-C thresholding, the final post processing phase removes the isolated pixel by morphological cleaning operation. Temitope Mapayi et al [9], produced energy information about the image using Gray Level Cooccurrence Matrix(GLCM). The threshold values were computed from the GLCM energy information to vessel segmentation. Swati Gupta et al [10], classified the retinal fundus images based on the eliminating the optical disc, extraction and removal of blood vessel followed by retinal classification using SVM and KNN classifiers.

Zafer Yavuz et al [11], presents a method for segmentation which includes four stages: the first stage prepared dataset for segmentation; Gabor, Frangi, and Gauss filters are used for enhancement process before a top-hat transform; in order to extract binary vessel, the hard and soft clustering technique can be used which includes K-means and Fuzzy C-means (FCM) and the final post processing stage removes the falsely segmented isolated regions. SohiniRoychowdhuryet.al [23], presents a new approach called unsupervised iterative blood vessel segmentation algorithm, the vessel network is enhanced using top hat transform and estimate the vasculature by global thresholding. By region growing method new pixels are identified and segmented.

Jingdan Zhang et al[15], constructs the feature vector with green channel intensity for blood vessel segmentation further the vessels are enhanced using morphological operation. The feature vector is defined in multi dimensional order. The Neural Network based Self Organising Map (SOM) is introduced for pixel clustering.

Khan Bahadar Khan et al [16], proposed the Generalised Linear Model (GLM) regression and Frangi filter for enhancement and separate the vessels by masking and moment preserving threshold value. K.S. Sreejini et al [12], presents improved multiscale matched filter for noise suppression and Partial Swarm Optimization method is used for vessel identification. The Gaussian Matched filter is applied for better accuracy. Chengzhang Zhu et al[5], introduced, a supervised method based on Extreme Learning Machine (ELM) to segment retinal vessel.

III.PROPOSED WORK

There are different approaches for blood vessel detection in DR. The patient retinal images are obtained at different environment for vessel identification. The delineation of retinal blood vessel plays a major role in retinal image analysis. The method used for vessel identification is depends on the Imaging modality and application domain, each method has its own pros and cons depending on the application environment. Correct interpretation of retinal image is vital in many eye pathologies for the ophthalmologist. DR is a severe and end complication of Diabetes in retina [17]. DR is initially identified by the existence of exudates. A liquid with protein content and cellular debris that has emitted by the blood vessels and has been dropped in tissues or on tissue surfaces which causes DR. Hence exudate detection is the most significant for the early detection of DR. Therefore, the accurate and automated blood vessel segmentation method is needed even though several methods exist. To identify the existence of exudates, separation of blood vessels is mandatory. The proposed work has been implemented in MATLAB environment. The overall proposed work is divided into three phases, (1) Pre-processing (2) Retinal blood vessel segmentation (3) Validation.

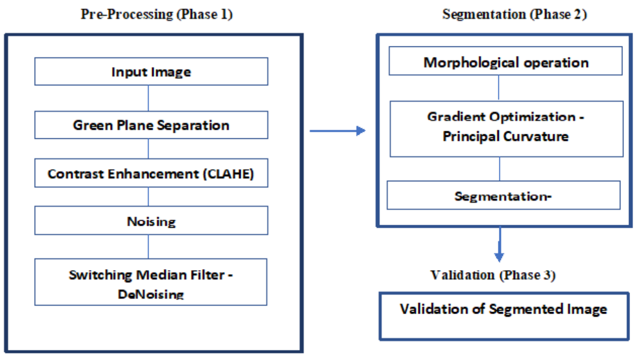

Fig 1: Retinal Blood Vessel Segmentation

PREPROCESSING

This phase concentrates on Image enhancement. The visual quality of the images are improved by using Image enhancement techniques. This makes the image clear for human observation or machine analysis.

DATASET:

The Proposed work is tested by using the DRIVE database, it is a collection of fundus images, These image photographs are collected from DR screening program in Netherland. The screening process includes 400 person images between the age group 25-90, from the 400 samples forty photographs have been arbitrarily selected, in that 7 images shown the early diabetic retinopathy and 33 images do not shown the possibilities of diabetic retinopathy. All the fundus images are in JPEG format [22].

GREEN PLANE SEPARATION

The proposed work starts with pre-processing phase, In this phase the retinal fundus image is transformed into green channel image. In order to achieve better segmentation the input fundus images are Pre-processed. Most of the researchers often use the green channel images for image analysis, the green channel of the color image produces clear image than the blue and red channels, and it produces the best physiological structures with blood vessels for image observation. Due to low contrast and saturation the red channel do not produce the clear image and the noise is more in blue channel [15] [19].Figure 2 illustrates the Input fundus image and corresponding Red, Green and Blue Channel images.

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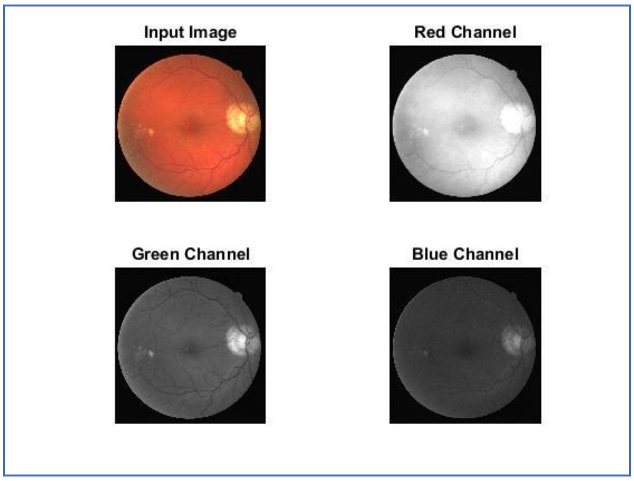

Figure 2: Input Fundus Image, Red, Green and Blue Channel Images.

CONTRAST ENHANCEMENT (CLAHE)

Contrast Limited Adaptive Histogram Equalization (CLAHE) is an advance method of Adaptive Histogram Equalization (AHE). The main drawback of AHE is over amplifying the noise. [13] CLAHE method can be applied on minor sections of the image and it avoids overamplification. The entire image is converted into different tiles, the contrast is improved in each tile, therefore the histogram of output region approximately matches the histogram specified by distribution parameter. The artificially induced boundaries are eliminated by bilinear interpolation method, then the neighbouring tiles are combined after enhancement. The AHE is work on the homogeneous region whereas CLAHE can be applied over both homogeneous and heterogeneous regions [14] [18]. In the proposed work, the size of each region was 8×8 pixels with 128 bins for the histogram. Figure 3 shows the results of applying the CLAHE on the green-channel images.

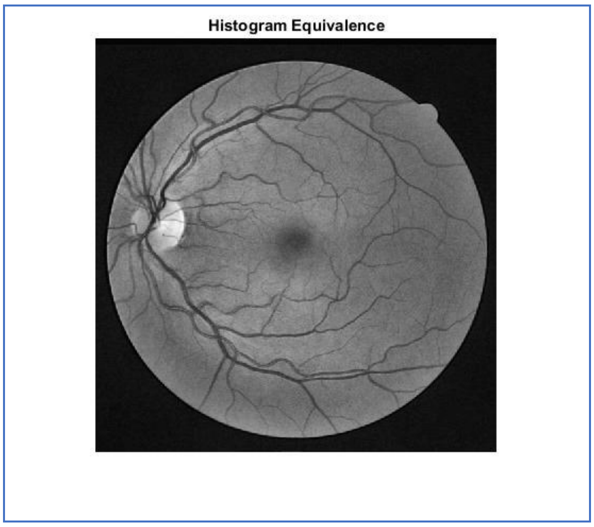

Figure 3: CLAHE Image

MEDIAN FILTER (NOISING AND DENOISING)

The images are noised due to environmental factors and external causes in transmission system. The noising and denoising technique was introduced to verify the accuracy of the algorithm, the salt and pepper noise is inserted in to the image. In order to achieve better vessel segmentation, the noises are removed in the fundus images. These noises are reduced by the filters. Smoothening is the process of removing the noise and preserving the edges [20]. Since this work uses the DRIVE database fundus images, the 'salt and pepper' noise is added on the input image. The salt and pepper noise is occurred due to the analog-to-digital conversion, bit errors in transmission, etc. Among all the filters the median filters works better to remove the 'salt and pepper' noise than other filters [16][21]. Figure 4 explains the Nosing and Denoising Images.

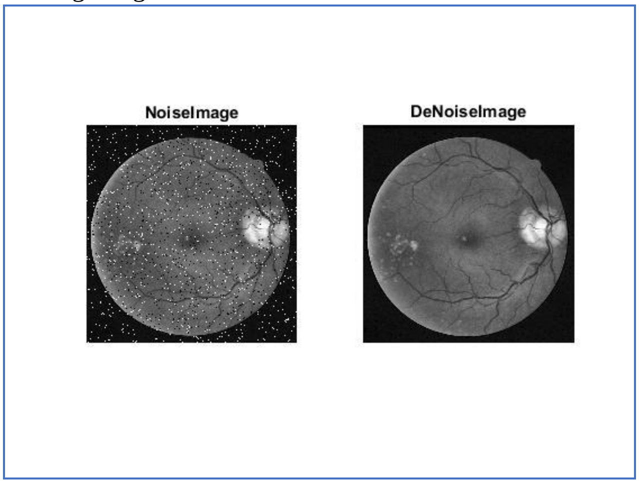

Figure 4. Noising and Denoising Image

SEGMENTATION

This phase concentrates on morphological process, Principal curvature based gradient optimization followed by removing small objects.

MORPHOLOGICAL PROCESS

Mathematical Morphology is the process of retrieving the image sub components, which are useful to define the image shape, edges and boundaries.. Most of the image pre-processing and post processing methods uses Morphological operations which includes filtering, thinning and pruning. Erosion & dilation are the primitive operations in morphology and it works on binary images. These operations are useful to identify, modify and operate the image features existing in the image and manipulate the images based on their shapes. The sequence of algebraic arithmetic operators are used to define the operations. A Structuring element is a matrix that is applied on the image which identifies and define the neighbourhood pixels. The dimension and profile of the structuring element depends on the matrix dimensions and elements in the matrix. The neighbourhood pixels are identified based on the *origin* of the structuring element. Dilation is the process of expanding the image or object by a specified structuring element to fill the holes and disconnected region. $A \oplus B$ denotes the dilation of image A with respect to the structuring element B. The structuring element B is located with its origin at (x,y) and the new pixel value is calculated by equation (i). [24]

$$g(x,y) = \begin{cases} x & B \text{ hits } A \\ y & \text{otherwise} \end{cases} \quad \text{(i)}$$

The dilation process is described in set language as follows in equation ii:

$$A \oplus B = \{(Z \mid (B)_z \cap A \neq \phi)\} \quad \text{(ii)}$$

The Erosion is a process of shrinking the image by the structuring element. $A \ominus B$ denotes the erosion of image A with respect to the structuring element B. The origin is at (x,y).The new pixel value is define as equation iii.

$$g(x,y) = \begin{cases} x & B \text{ hits } A \\ y & otherwise \end{cases} \quad \text{(iii)}$$

The erosion process is described in set language as follows in equation iv:

$$A \ominus B = \{(Z \mid (B)z \subseteq A)\} \quad \text{(iv)}$$

The morphological operations are accomplished by combining the sequence of erosions and dilation process, these are called composite operations. The opening and closing operations are compound operations which can be combined depending upon the application. A ◦ B denotes the opening operation of an image A with structuring element B, described in equation v and vi.

$$A \circ B = (A \ominus B) \oplus B \quad \text{(v)}$$

$$A \circ B = \cup \{(B)z \mid (B)z \subseteq A\} \quad \text{(vi)}$$

The A · B denotes the closing operation of an image A with the structuring element B.

The equation (7) describes the dilation operation followed by erosion,

$$A.B = (A \oplus B) \ominus B \quad (7)$$

The proposed work applies erosion operation on the input retinal image, and that will smoothen the image. The opening operation is performed on the retinal image, which includes two operations such as erosion and dilation. These operation produces the eroded mask image for next process.

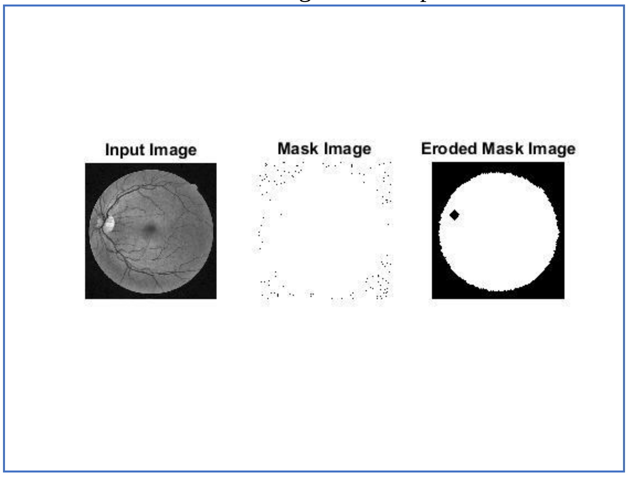

Figure 5: Mask And Eroded Mask Image

PRINCIPAL CURVATURE
(GRADIENT OPTIMIZATION)

According to differential geometry, the two principal curvatures at a given point of a surface are the eigen values of the shape operator at the point. The principal curvatures works on each point of the image and it estimates the minimum and maximum bending of a regular surface of an image. The two principal curvatures are represented as eigenvalues at the point. These curvatures measure surface bending in different directions at that point. The below Hessian matrix represents the local shape characteristics of the surface at a specific point,

$$H(X,\sigma D) = \begin{bmatrix} Ixx(x,\sigma D) & Ixy(x,\sigma D) \\ Ixy(x,\sigma D) & Iyy(x,\sigma D) \end{bmatrix}$$

where Ixx, Ixy and Iyy are the second-order partial derivatives of the image estimated at the point x and σD represents the Gaussian scale of the partial derivatives. Maximum principal curvature is determined in every pixel of the Gaussian filtered Image. The element wise multiplication of eroded mask image with maximum principal curvature produces the maximum principal curvature mask image, which acquires the direction and size of the blood vessels.

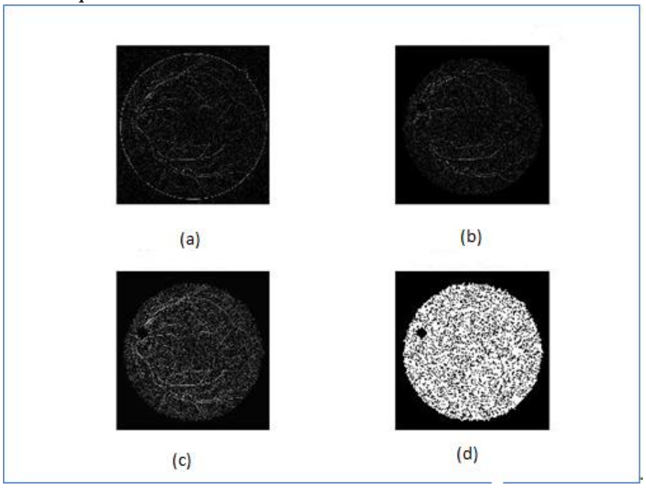

Figure 6:
(a) Maximum Principal Curvature Image
(b) Maximum Principal Curvature Mask Image
(c) New Principal Image
(d) Vessels Image CLAHE& Remove Small Objects from Binary Image

CLAHE prevents the over amplification and operates on small regions in the image. This will produce contrast enhanced retinal vessel image and further the unnecessary small objects are removed from the image. In order to determine the accuracy of the system the ground truth image of the input image is compared with segmented image.

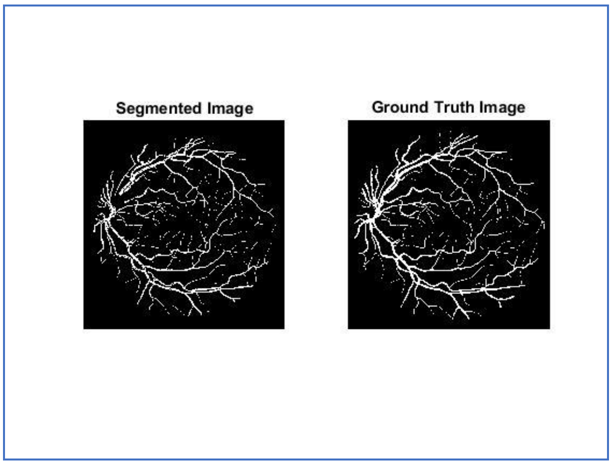

Figure 7: Segmented and Ground Truth Image

VALIDATION

The performance of the retinal segmented image is assessed through statistical analysis.

Based on Accuracy, Sensitivity & Specificity values, the performance is measured. Accuracy refers to the efficiency of a method or system. Sensitivity defines the measurement of correctly identified parts from the actual positives, also known as True Positive rate. Whereas the Specificity measures the amount of negatives from the actual negatives. Accuracy, Sensitivity & Specificity values are identified by using the following equation,

TP = True Positive (Correctly Selected),
FP= False Positive (Mistakenly Selected),
TN= True Negative (Correctly Rejected),
FN= False Negative (Mistakenly Rejected).
Accuracy= TP + TN / (TP+FP+TN+FN) (or)
TP+TN/(row * Column)
Sensitivity or True Positive Rate = TP / (TP + FN)
Specificity or True Negative Rate = TN / (TN + FP)

Algorithm for computing TP, TN, FP & FN
1. Retinal vessel segmented image I is given as first Input
2. Hand labelled ground truth image T is given as second output
3. Calculate the size of the image by m & n
(m represents row and n represents column.)
4. Each pixel of segmented vessel network image I is compared with
ground truth T and calculate the TP, TN, FP & FN
5. Print TP, TN, FP & FN;

IV.RESULT AND DISCUSSION

The drive database be made up of of 40 retinal fundus photographs in which 33 images are normal and 7 images has the possibilities of mild DR. The proposed work is applied to all 40 images. This proposed work begins with pre-processing phase in which the image quality is improved by applying histogram analysis. The pre-processing technique CLAHE is used for improving image quality and reduces the noise. The overall procedure consists of three essential phases. The first phase involves enriching the image by extracting green channel of the image, as the green channel produces the more clear and contrast image than the red and blue channels. The contrast of green channel image is further enhanced by CLAHE method. The enhanced image is smoothened by adding and removing the noise. The second step includes the segmentation process, In this step mathematical morphological operation erosion is applied on the smoothened image and also maximum principal curvature is obtained from gradient optimization technique. In the third step, the each and every pixel of segmented image is compared with ground truth image.

Table 1: Performance Evaluation

IMAGE	ACCURACY	SENSITIVITY (TPR)	SPECIFICITY (TNR)
1	0.9645	0.74485	0.99157
2	0.96382	0.77901	0.98871
3	0.94916	0.74583	0.9716
4	0.9633	0.77439	0.98446
5	0.96285	0.75856	0.98792
6	0.962	0.75493	0.98927
7	0.96304	0.76253	0.98622
8	0.96672	0.7547	0.99122
9	0.9677	0.74128	0.99314
10	0.96454	0.72267	0.99297
11	0.95885	0.71648	0.98933
12	0.96622	0.74812	0.99206
13	0.95961	0.73692	0.9903
14	0.96664	0.74114	0.99128
15	0.95908	0.73181	0.97517
16	0.96614	0.75256	0.993
17	0.97008	0.76121	0.9944
18	0.96853	0.75419	0.99075
19	0.96232	0.71924	0.9903
20	0.97401	0.76382	0.99483
21	0.97149	0.74928	0.9942
22	0.96326	0.73907	0.99157
23	0.98173	0.82369	0.99426
24	0.95874	0.7784	0.98665
25	0.96517	0.7772	0.98848
26	0.96027	0.76669	0.97761
27	0.96399	0.74228	0.99071
28	0.96202	0.75839	0.98861
29	0.96154	0.7291	0.98726
30	0.96075	0.74082	0.98024
31	0.97817	0.76027	0.99556
32	0.96799	0.7495	0.9922
33	0.96617	0.73586	0.99168
34	0.9542	0.77157	0.97355
35	0.96618	0.75778	0.99001
36	0.95631	0.76132	0.98404
37	0.96679	0.75857	0.99117
38	0.96563	0.74065	0.99284
39	0.96376	0.732	0.99154
40	0.96806	0.73735	0.99152
Average	**0.96453325**	**0.751851**	**0.988805**

The proposed method is tested by relating the segmented image with the corresponding ground truth images pixel by pixel. This method produced the average sensitivity and specificity as 0.752 and 0.989 respectively. The average Accuracy is 0.965. Table 2 shows comparative analysis of existing methods and proposed method with Accuracy, Sensitivity and Specificity parameters.

Table 2: Performance Comparison of Other Methods

SL. NO	METHOD	ACCURACY	SENSITIVITY (TPR)	SPECIFICITY (TNR)
1	Roychowdhury et al. 2015 [7]	0.952	0.725	0.983
2	Jyotiprava Dash et al 2017 [8]	0.955	0.719	0.976
3	Temitope Mapayi et al, 2015 [9]	0.9511	0.7650	0.9724
4	Swati Gupta 2015 [10]	0.86	0.87	1
5	Zafer Yavuz 2017 [11]	0.9571	0.6102	0.9905

6	SohiniRoy chowdhury et al 2015 [23]	0.949	0.739	0.978
7	Jingdan Zhang et al, 2015 [15]	0.940	--	--
8	Khan Bahadar Khan 2017 [16]	0.960	0.747	0.980
9	K.S. Sreejini et al 2015 [12]	0.9633	0.7132	0.9866
10	Chengzha ngZhu et al 2016 [5]	0.9607	0.7140	0.9868
11	**Proposed Method**	**0.965**	**0.752**	**0.989**

For pathological cases, the efficacy of the proposed system has been confirmed by comparing the existing methods, displayed in Table 2. The tabulated results clearly specified that the proposed algorithm outperforms many other vessel extraction methods reported in literature for abnormal cases.

V.CONCLUSION

The proposed work is able to extract the blood vessel from the input test image. This work applied CLAHE and median filter for Histogram Equivalisation and smoothening the image. The smoothened image is segmented by the combined morphological operation and maximum principal curvature determination, and also remove the small object not connected to the vessel network. This approach is tested with DRIVE database, 40 images are tested and mean value of Accuracy, Sensitivity and Specificity is calculated for validating the proposed system. This system can produce 96.5 % Accuracy, 75.2% Sensitivity and 98.9% Specificity. Hence, this approach is reliable one for extracting vessels in the vessel network. The new methodologies to identifying the eye diseases at the early stage are the interest of future work.

REFERENCES

1. D.N.D. Harini, D. Lalitha Bhaskari, "Automatic Image Segmentation Using Grid-Based NcutAnd RAG", *Int. J. Image Mining, Vol. 1, No. 4, 279-295, 2015.*
2. Gehad Hassan, Nashwa El-Bendary, Aboul Ella Hassanien, Ali Fahmy, AbullahM.Shoeb, and Vaclav Snasel, "Retinal blood vessel segmentation approach based on mathematical morphology", International Conference on Communication, Management and Information Technology (ICCMIT), Elsevier, Procedia Computer Science 612 – 622, 2015.
3. Mohammad Sohrabinia, SaeidSadeghian, DadfarManavi,, "Application of Image Processing And Image Analysis Methods For Large Scale Map Revision", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B4. Beijing 2008.
4. K.Geethalakshmi, Dr.V.S.Meenakshi, "A Survey on Disease Identification And Blood Vessel Segmentation In Human Retinal Images", International Journal of Advance Research in Science and Engineering, Vol 6, Issue 12, Dec 2017.ISSN: 2319 8354.
5. ChengzhangZhu,BeijiZou,RongchangZhaoa,cJinkaiCuiac,Xuanchu Duanbc,ZailiangChenac,YixiongLiangac, "Retinal vessel segmentation in colour fundus images using Extreme Learning Machine", Computerized Medical Imaging and Graphics, Volume 55, January 2017, Pages 68-77
6. Mahendran Gandhi, R.Dhanasekaran, " Diagnosis of diabetic retinopathy using morphological process and SVM classifier", 2013 IEEE International Conference on Communication and Signal Processing, 2013.
7. Roychowdhury S, Koozekanani DD, Parhi KK. Blood vessel segmentation of fundus images by major vessel extraction and subimage classification" IEEE J Biomed Health Inf 2015; 19(3):1118e28.
8. Jyotiprava Dash, NilamaniBhoi, "A thresholding based technique to extract retinal blood vessels from fundus images", http://www.journals.elsevier.com/future-computing-and-informatics-journal/, Future Computing and Informatics Journal 2 (2017) 103e109.
9. Temitope Mapayi, SerestinaViriri, Jules-Raymond Tapamo, "Adaptive Thresholding Technique for Retinal Vessel Segmentation Based on GLCM-Energy Information", Hindawi Publishing Corporation Computational and Mathematical Methods in Medicine, Volume 2015, Article ID 597475, 11 pages.
10. Swati Gupta, Karandikar A.M. "Diagnosis of Diabetic Retinopathy using Machine Learning", Gupta and Karandikar, J Res Development 2015, 3:2http://dx.doi.org/10.4172/jrd.1000127.
11. Zafer Yavuz and CemalKöse "Blood Vessel Extraction in Color Retinal Fundus Images with Enhancement Filtering and Unsupervised Classification", Hindawi Journal of Healthcare Engineering Volume 2017, Article ID 4897258, 12 pages.
12. K.S. Sreejini*, V.K. Govindan, "Improved multiscale matched filter for retina vessel segmentation using PSO algorithm", Egyptian Informatics Journal (2015) 16, 253–260
13. Marwan D. Saleh, C. Eswaran, Ahmed Mueen, "An Automated Blood Vessel Segmentation Algorithm Using Histogram Equalizationand Automatic Threshold Selection", Journal of Digital Imaging, Vol 24, No 4 (August), 2011: pp 564-572.
14. Niladri Sekhar Datta, Himadri Sekhar Dutta, Mallika De, Saurajeet Mondal. "An Effective Approach: Image Quality Enhancement forMicroaneurysms Detection of Non-Dilated Retinal Fundus Image", Elsevier, International Conference on Computational Intelligence: Modeling Techniques and Applications (CIMTA) 2013.
15. Jingdan Zhang, Yingjie Cui, Wuhan Jiang, and Le Wang, "Blood Vessel Segmentation of Retinal ImagesBased on Neural Network", Springer International Publishing Switzerland 2015ICIG 2015, Part II, LNCS 9218, pp. 11–17, 2015.
16. KhanBahadar Khan, Amir A. Khaliq, MuhammadShahid, "A Novel Fast GLM Approachfor Retinal Vascular Segmentation and Denoising", Journal Of Information Science And Engineering 33, 1611-1627 (2017).
17. Anu J. Mohan, Jayasree M. J."Techniques for the Detection of Blood Vessels in Diabetic Retinopathy", IOSR Journal of Computer Engineering (IOSR-JCE) e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume17, Issue 4 Ver. I (July – Aug. 2015),PP 77-81.
18. Garima Yadav Saurabh Maheshwari ; Anjali Agarwal, "Contrast limited adaptive histogram equalization based enhancement for real time video system", IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI)2014.
19. Thomas Walter, Pascal Massin, Ali Erginay, Richard Ordonez, Clotilde Jeulin, Jean Claude Klein, "Automatic detection of Microaneurysms in color fundus images", Medical Image Analysis, Vol 11, Issue 6, Dec 2007, Pg. 555-566.
20. C. GokilavaniN. Rajeswaran; V. J. Arul Karthick; R. Sathish Kumar; N. Thangadurai, "Comparative results performance analysis of various filters used to remove noises in retinal images", IEEE 2015 Online International Conference on Green Engineering and Technologies.
21. Nalin Kumar, M.Nachamai, "Noise Removal and Filtering Techniques used in Medical Images" Oriental Journal Of Computer Science &Technology,ISSN: 0974-6471, March 2017, Vol. 10, No. (1): Pgs. 103-113.
22. http://www.isi.uu.nl/Research/Databases/DRIVE
23. SohiniRoychowdhury∗, Member, IEEE, Dara D. Koozekanani, Member, IEEE, and Keshab K. Parhi, Fellow, IEEE""Iterative Vessel Segmentation of Fundus Images", IEEE Transactions On Biomedical Engineering, Vol. 62, No. 7, July 2015.

24. Aqeel F Aqeel ; Subra Ganesan, "Retinal image segmentation using texture, thresholding, and morphological operations", 2011 IEEE International Conference on Electro/Information Technology PP-(1-6).

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