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RETINAL BLOOD VESSELS SEPARATION - A SURVEY

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ABSTRACT

Segmenting blood vessel from the retinal image is important for detecting many retinal vascular disorders. Diseases which are all affecting the blood vessels of the eye are known as Retinal vascular disorders. Vessel separation of retinal image is a fundamental step in finding the affected area of vascular. Some of the disorders of retinal vascular are Diabetic Retinopathy (DR), Hypertensive Retinopathy, Retinal Vein Occlusion (RVO), Central Retinal Artery Occlusion (CRAO), and Glaucoma. For identifying diseases and changes in the retina Retinal Blood Vessel Separation (RBVS) is important. For segmenting the blood vessel and early detection of these disorders many different approaches and algorithms have been developed; few of them were discussed in this paper. In this paper, various existing approaches, methodologies, and algorithms for separating the vessels from the retinal image were analyzed.

KEYWORDS: Segmentation, Retina, Blood vessel, Diabetic Retinopathy.

Eyesight is one of the most important and valued senses in Human Beings. Some eye diseases have no symptoms in their early stages. Diabetic retinopathy (DR) is a retinal blood vessel disorder of patients who are affected by diabetes mellitus. Diabetes affects the eyes and reduces the strength of blood vessels in the retina. Because of Strength loss, vessels may break down and that may lead to leakage of fluid into the center of the retina (macular edema) or growth of some abnormal blood vessels over the retina surface may lead to bleed and scar. This may cause loss of vision.

DR creates new blindness in adults of developed countries, including India. Almost 31.7 million Indians affected by Diabetic and related complications like vision loss, stroke, and heart failure. DR screening is important for reducing disease burden reported World Health Organization (WHO).

The regular direct visual examination is useful for detecting Other retinal membrane disorders. In diabetic retinopathy diagnosis blood vessel structure of retina has an important role. For segmenting blood vessel several methods are available.

Features of blood vessels like abnormal branching, tortuosity, entropy, and neovascularization are highlighted during Vessel segmentation. Using automatic RBVS, specialized physicians can provide speed diagnosis and increase their diagnostic performance. Screening image processing highlights anomalies situation, compares this image to the previous images and demonstrates the transformation of the retina [Klein and Klein, 1995].

Analysis of various section described in this paper as follows. Section II is for providing detailed information about RBVS. Section III is focused on showing the different techniques and approaches to RBVS. Section IV is giving the descriptive study of few existing work. Section V presents the conclusion.

Blood vessel structure of retina has an important role in diabetic retinopathy diagnosis. Various approaches used for segmenting the vessels are categorized in figure 1. Categorization is performed based on the algorithms, and the methodologies used for an image- processing.

These methods use distinct techniques for image processing, and each has different merits and demerits in segmenting the blood vessel [ETDRS, 1991]. Hybrid algorithms are developed because of this property.

Detecting blood vessel of the retina from an image is a continuous process; If it is not executed properly we cannot obtain best- segmented result image. Before performing segmentation, the image should be pre-processed for removing the noise and for enhancing the contrast between blood vessel of the retina and its background.

The segmentation process is fed with an enhanced image for obtaining the segmented image which is further applied to thresholding to obtain the threshold image. Finally, post-processing applied to an image for removing false pixels and obtain the edge map. Figure 2 depicts the steps for the extraction of vessels from retinal image.

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VESSEL SEPARATION TECHNIQUES FOR RETINAL IMAGE

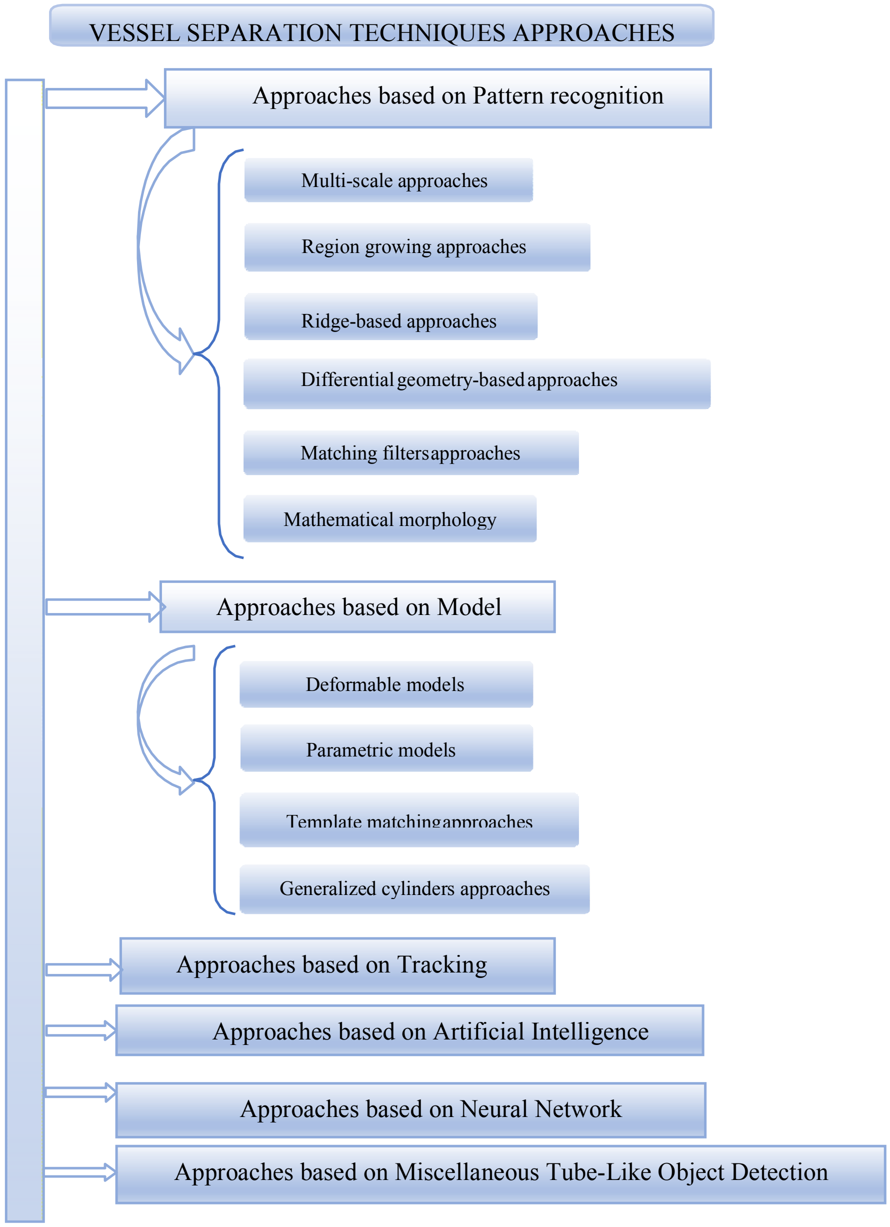


Figure 1: Classification of vessel separation approaches

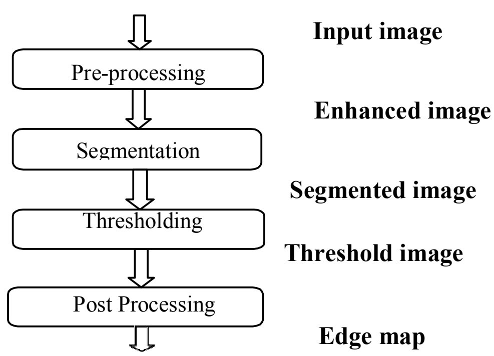


Figure 2: Steps for blood vessel separation

VARIOUS EXISTING TECHNIQUES FOR RETINAL BLOOD VESSEL SEPARATION

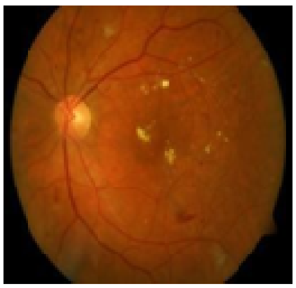
Table 1: Summary of various existing techniques

S.NO	Author name	Year	Image processing technique	Segmentation Technique	Performance metric
1	Li et. al., 2017	2017	Robust Segmentation Based on Reinforcement Local Descriptions	SVM	Acc, SN, SP
2	Kaur and Singh, 2016	2016	Fuzzy C-Means and Neutrosophic Approach for Disease Detection and Segmentation	Neutrosophic & Fuzzy C-Means	Acc, SN, SP, PPV
3	Binooja and Nisha, 2015	2015	Artery/Vein Classification Using Neural Network	Feed Forward Neural network	Acc, SN, SP
4	Hassanien et. al., 2015	2015	Vessel Localization using FCM, PS, & Bee Colony	ABC & PS	Acc, SN, SP
5	Akhavan et. al., 2014	2014	Vessel Segmentation using Fuzzy segmentation	Fuzzy C-Means	Acc, SN, SP, PPV, PLR
6	Fathi and Naghsh-Nilchi, 2013	2013	Vessel diameter estimation and Vessel Segmentation using Wavelet-based	Matched Filtering	Acc, SN, SP, AUC, PPV
7	Radha and Lakshman, 2013	2013	Morphological process and clustering technique for Image analysis	K-means Clustering	Not mentioned
8	Condurache and Mertins, 2012	2012	Paradigm of Hysteresis binary-classification	Supervised method	Acc, SN, SP
9	Fraz et. al., 2012a	2012 a	Morphological bit-plane slicing and Vessel centerline detection	Morphological Processing	Acc, SN, SP, TPR, FPR, PPV
10	Fraz et. al., 2012b	2012 b	A survey of Segmentation methodologies in retinal images	Comparison Method	Acc, SN, SP, TPR, FPR, PPV
11	Fraz et. al., 2012c	2012 c	Decision trees for Ensemble classifier	Supervised method	Acc, SN, SP, AUC FDR, PPV
12	Dey et. al., 2012	2012	FCM based segmentation	Fuzzy C-Means	Acc, SN, SP
13	Marin et. al., 2011	2011	Supervised Segmentation using Moment Invariants-Based Features	Supervised method	Acc, SN, SP, AUC, PPV
14	Miri and Mahloojifar, 2011	2011	Image analysis using multi-structure morphology and Curvelet transform	Morphological Processing	TPR, FPR, Acc
15	You et al., 2011	2011	Semi-supervised segmentation using the radial projection	Supervised method	Acc, SN, SP
16	Yuan et al., 2011	2011	Vessel enhancement using line integrals and optimization	Model-Based Methodologies	AUC
Acc – accuracy; AUC – area under curve; PPV- positive predictive value; SN – sensitivity; TPR- true positive rate; FPR-false positive rate; PLR- positive likelihood ratio; SP – specificity					

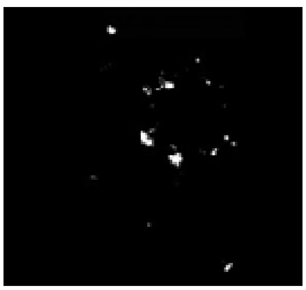
DESCRIPTIVE STUDY OF FEW EXISTING WORKS

Fuzzy C-Mean And Neutrosophic Approach For Disease Detection And Segmentation

Segmentation of retinal veins and Disease detection proposed by Kaur and Singh, 2016. This approach contains three steps for segmenting the blood vessels. That is 1) Image preprocessing 2) Unsupervised approach 3) Image post- processing.

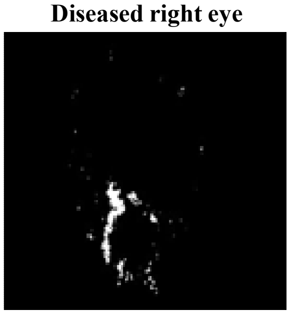


Diseased Left Retina



Disease detected portion

Diseased right eye



Disease detected portion

Figure 3: Result of Ishmeet Kaur and Lalit Singh

Image preprocessing used for enhancing the quality of the image and making further calculation simple. This step includes extraction of the color channel, enhancing the contrast, unsharp masking and calculating magnitude of the image. The result of the preprocessing stage feed as input for an unsupervised approach.

The unsupervised approach is the clustering process it uses two algorithms, fuzzy c-mean clustering and neutrosophic. This step applied for further differentiation of the image pixels into vessels, non-vessels and indeterminate. Mathematical morphological operations are included in post-processing phase, and the final segmented image is obtained.

Table 2: Result of Ishmeet Kaur and Lalit Mann Singh

Dataset	Average		
	Accuracy (Acc)	Sensitivity (SN)	Specificity (SP)
Drive	98.74%	98.38%	94.78%

With the above result, they detected affected portion in the DIARETDB1 dataset with 99.6% of sensitivity. It provides better exactness in vessel segmentation; this may be the powerful tool for diagnosis and useful in early detection of DR

ARTERY/VEIN CLASSIFICATION USING NEURAL NETWORK

Binooja and Nisha, 2015 proposed the automatic Artery/Vein classifications using NN. This vessel classification of retinal images is useful for finding changes in the vascular. The proposed method consists of 1) Graph generation 2) Graph Analysis 3) A/V classification 4) Disease Identification.

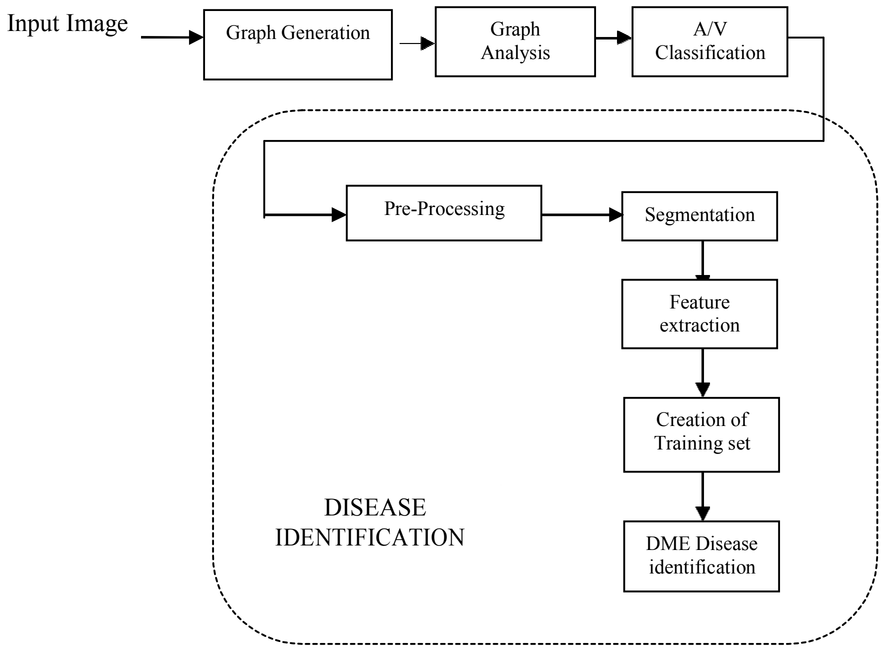


Figure 4: Block Diagram for A/V Classification of Disease Identification

Graph generation algorithm is proposed by Binooja & Nisha for Artery/Vein (A/V) classification. Binooja & Nisha proposed block diagram shown in Fig.3. Steps in the proposal as follows a) Vessel Segmentation – this step of assigns a label to every pixel in the image and locates boundaries. b) Vessel centerline extraction - used for obtaining minimally connected centerline vessel graph. c) Graph Extraction - finding the intersection points and terminal points, and removing intersection point from vessel centerline graph with its neighbors. d) Graph Modification – identifies the error using i) Node splitting ii) Missing a link and iii) False link and modifies the graph if the error identified.

Graph Analysis analyzes various numbers of intersection points and extracts node's information using node classification method. Then every sub-graph is labeled using suitable algorithm till covering the whole retinal image. The result of this step is a graph with various labeling to its every disjoint sub-graph. Depends on label A/V Classification assigns artery and vein.

Table 3: Result of Binooja & Nisha, 2015

Dataset	Accuracy (Acc)
DRIVE	90%,
VICAVR	92%
INSPIRE-AVR	98%

Next step, Disease Identification using Feed Forward Neural network (FFN) to distinguish disease. The framework proposed by Binooja & Nisha has better accuracy, speed, and great execution. This system classifies the retinal images as severe [$Acc \geq 0.965$, $SN \geq 0.80$, and $SP \geq 0.993$] and moderate [$Acc \geq 0.966$, $SN \geq 0.802$, $SP \geq 0.992$].

VESSEL SEGMENTATION ALGORITHM USING FUZZY SEGMENTATION

In Akhavan and Faez, 2014, proposed the following segmentation algorithm using fuzzy segmentation. This algorithm with four main parts: 1) Preprocessing, 2) Processing with two phases, 3) Combining.

Preprocessing includes noise elimination, background normalization and thin vessel enhancement using the green channel of the retinal color images. Processing includes two phases, 1) Vessel centerline detection, and 2) Fuzzy vessel segmentation. Before extracting, two results obtained from two previous steps are combined. Then the complete pixels belonging to the retinal vessels are extracted.

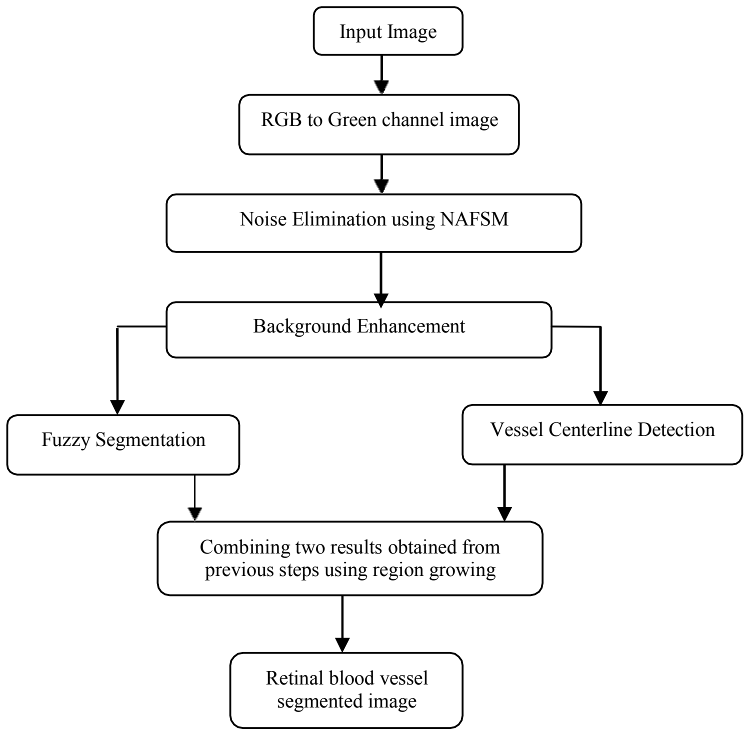


Figure 5: Retinal vessel segmentation functional diagram by Akhavan R. and Faez K., 2014

Table 4: Result of Akhavan R. and Faez K., 2014

Dataset	Accuracy (Acc)	Sensitivity (SN)	Specificity (SP)
DRIVE	95.13%,	75.52%	97.33%
STARE	95.30%	77.60%	96.80%

For making segmentation process easier and reducing the computational time the green channel is obtained from the RGB fundus image because it contains clear information and provides a maximum contrast. Noise Adaptive Fuzzy Switching Median Filter (NAFSM) applied for detecting noise pixels locations within the image and the noise to be eliminated.

After this step, to achieve complete segmentation, retinal vessels filled from start to the detected center-lines. For this, Fuzzy C- Means (FCM) clustering technique used by Akhavan R. and Faez K., 2014. In region growing, the pixels in the fuzzy segmentation image are combined to fill the vessel centerline pixel which is used as a primary point.

For a normal and abnormal image, this proposed vessel extraction algorithm has given a persistent performance. Noises are removed using NAFSM filter approach. Though, Sensitivity] is not up to the mark. This method can extract the vessel centers entirely, but not the actual width of the vessels. Here, PPV and PLR values are not mentioned.

FCM BASED SEGMENTATION

Dey et. al., 2012 proposed Fuzzy C-Means (FCM) based segmentation method. Initially, the retinal image’s green channel is converted into a grayscale image, because it has advantages like less noise and high contrast between background and vessel.

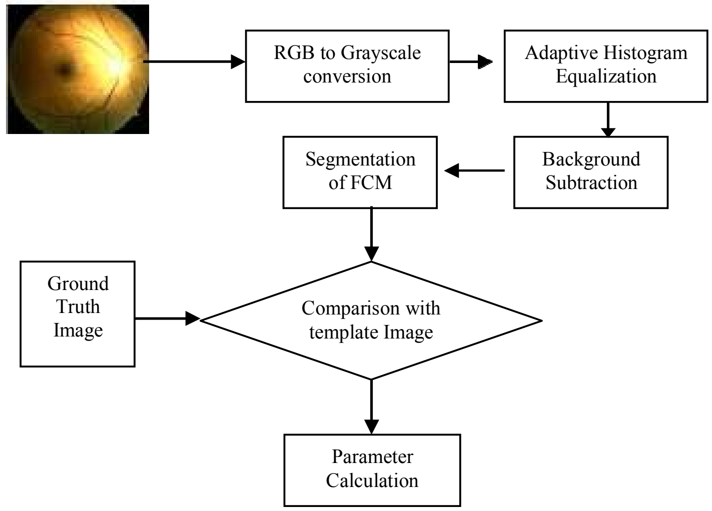


Figure 6: Blood vessel segmentation method

On the gray image, Adaptive histogram equalization is performed. Then, median filter technique is applied for subtracting background from the foreground of the image. After completing binarization method and filtering techniques, FCM applied to the image.

Finally, the resulting image compared with the ground truth image for identifying the corresponding disease. Performance measures like PPV, PLR, sensitivity, specificity, and accuracy have been calculated for the resulting image.

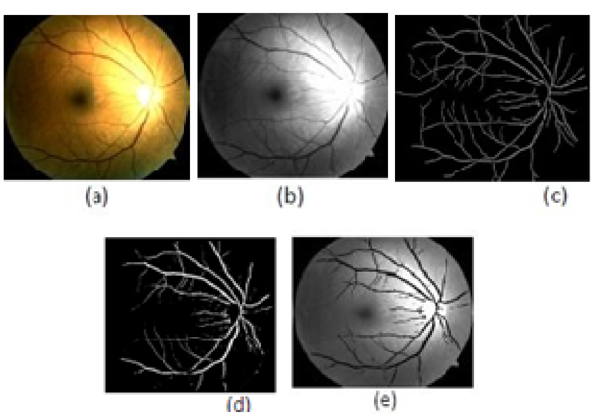


Figure 7: (a) Original image, (b) Image of grayscale, (c) Ground truth image, (d) Detected Vessel, (e) Image of the detected blood vessel.

This paper deals with the ground truth and FCM segmented retinal blood vessel. For proper segmentation, this algorithm expects good quality (sharpness, contrast, focus etc.) images. Adaptive local thresholding technique is used for detecting thick vessels in a normalized image. In this segmentation is done base on FCM.

Table 5: Result of Dey et. al., 2012

Matrices	Values
Accuracy (Acc)	95.03%
Sensitivity (SN)	95.03%
Specificity (SP)	~54.66%
PPV	95.08%
PLR	219.72

This proposed algorithm has given a very good performance. This algorithm gives importance to all finer information about blood vessels without referring thick or thin. However, this algorithm gives low Specificity.

CLUSTERING AND MORPHOLOGICAL PROCESS FOR IMAGE ANALYSING

An effective combination of multi-structure morphological process and segmentation techniques for retinal vessel and exudates detection given by Radha and Lakshman, 2013.

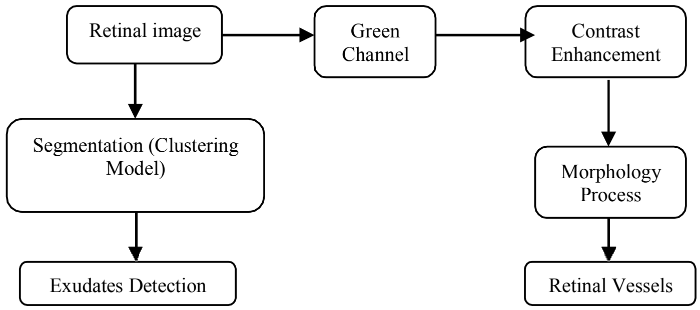


Figure 8: Block diagram proposed by Radha and Lakshman, 2013

At first, Retina Blood Vessels Detection was performed for Plane separation, Contrast Enhancement, Morphological Process. Then, segmentation Technique was used for exudates Detection. The first process is taken RGB image is converted into a grayscale image. After that bit plane separation, contrast enhancement and morphological processes like dilation, erosion, closing, and opening are used for extracting the blood vessel.

Next, Discrete Wavelet Transform (DWT) & Energy feature coefficients were applied to extract feature. Then, the extracted features were taken for training with Probabilistic Neural Networks (PNN). For differentiating the hard and soft exudates, K-means Clustering method was applied to segmentation. After that, the morphological process is applied for smoothing the exudates. Final image helped to determine whether the retina was in normal condition or not. The extracted exudates are shown in the following figure.

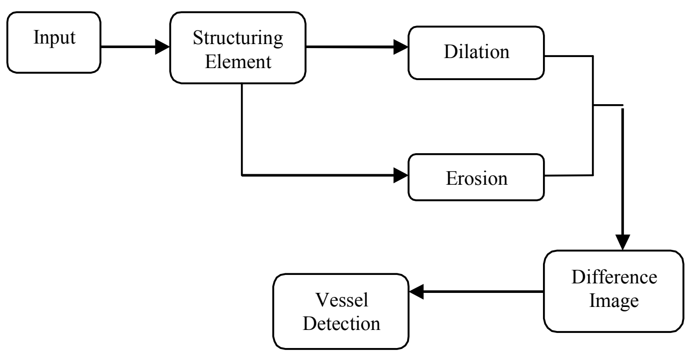


Figure 9: Flow diagram of vessel detection proposed by Radha et al.

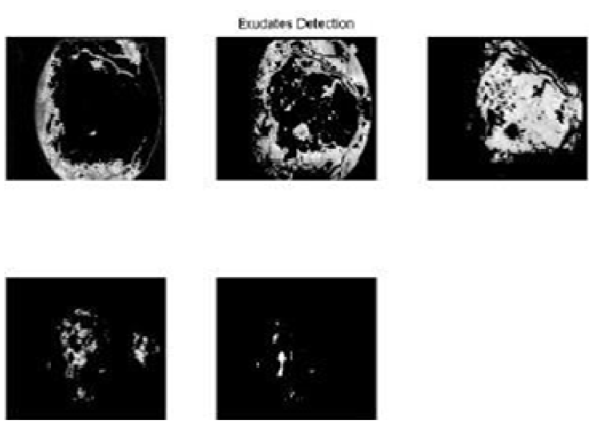


Figure 10: Extracted exudate

Here, the Process time was faster while comparing with another clustering with more number of data points. 110 images were tested and trained for producing a better result. It also provided better contrast enhancement, precise detection of retinal vessel and execute. Blood vessel edges were identified effectively by using the structure elements morphology.

However, the disadvantage this clustering algorithm is, the number of clusters K must be determined; it yields the different result for each time the algorithm is executed. Also, simple thresholding method was used, therefore, there was missing of some thin vessels. The author had not done a quantitative analysis of the work based on the parameters like accuracy, recall, specificity.

CONCLUSION

This paper presents different techniques used for segmenting the blood vessel and classifies existing blood vessel segmentation techniques. Blood vessel structure of retina has an important role in diabetic retinopathy diagnosis. RBVS is used to identify DR at an earlier stage. The accurate result of vascular segmentation is necessary for effectively screening and diagnosis most of the eye diseases. Many algorithms and techniques for segmenting the vessels have been proposed and developed. But still, it requires advanced techniques for accurate detection different eye diseases.

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