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Overview of Automatic Segmentation of Retinal Fundus Image for Medical Diagnosis

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Abstract- Nowadays segmentation of retina plays a major role in diagnosis of several diseases related to blood vessels like Glaucoma detection, Diabetics, Stroke prediction, Cardio Vascular Disease diagnosis, Myocardial Ischemia and other disease related to retina. Retinal fundus images are widely used in medical field for these diagnoses. Several blood vessels are found in the retina mainly arteries and veins. These blood vessels may be bifurcated, cross each other, may break in between. Manual segmentation and analysis of this image is tedious and time consuming. False detection of disease is also possible. Several researcher undergone research to automatically segment, classify and detect the disease perfectly with least amount of time. This paper deals with all ideas posted by each researcher on automatic segmentation and analysis of retinal fundus image for automatic prediction and detection of disease.

Keywords: **Retinal Vessel Segmentation, Graph cut algorithm, Neural Network, Supervised algorithm.**

I. INTRODUCTION

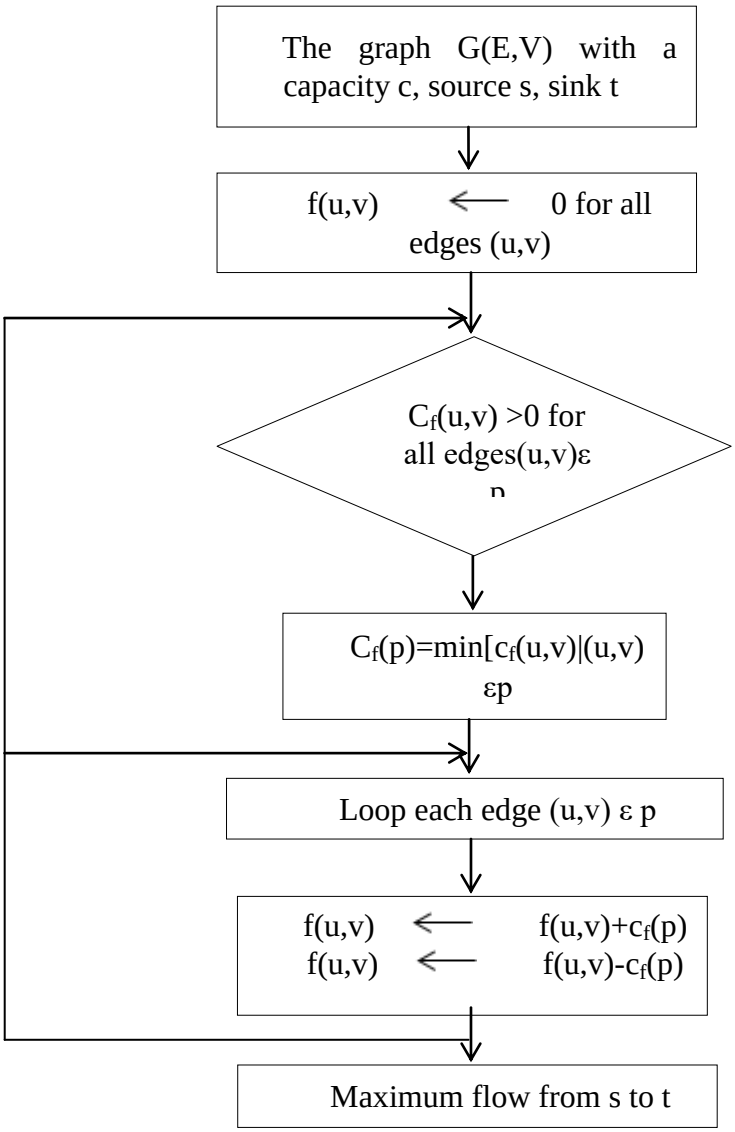
Machine learning history starts from 1990 gave way to automatic analysis of data which helps in reduction man power, time and effort. It also pave a way to increase accuracy, efficiency and ease to apply. In automatic segmentation of retinal fundus image machine learning technique is widely used. Pattern Recognition (PR) is the intelligent component of machine learning which deals with the diagnosis of medical image whish process the data and make decision based on the data processed.

Several approaches are utilized in recognizing pattern in the medical image. Major approach utilized is of two. One is Statistical approach and Syntactic approach. Recently third approach is also included in recognizing pattern, neural network. Neural network based recognition of pattern in medical image gives higher accuracy than other two approaches. Nowadays research focus on neural network based segmentation of medical images. The flow of pattern recognition technique in medical diagnosis include input source that is the image to be diagnosed, this image is further enhanced by using filter which removes noise in the image under diagnosis. The enhanced image is then segmented in order to extract the feature (region of interest), this feature extracted data is then fed to classifier which take decision based on the data applied. There are two ways in learning the data for recognition, one is supervised and other thing unsupervised. Supervised learning deals with trained data; by comparing train data with current data under process decision is made. While unsupervised learning deals with automatic decision making by applying certain machine learning algorithm [20].

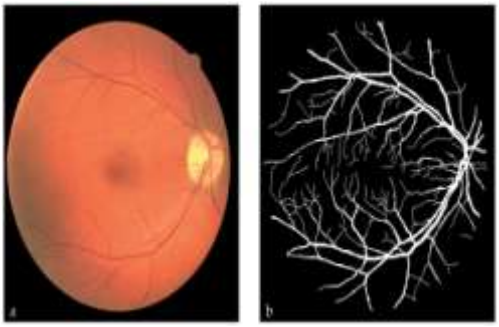
After pre-processing, the main step in analyzing the image is segmentation because the segmented image is primary input for further processing. We need to concentrate more on accurate segmentation. Automatic and accurate segmentation of image is focus of our paper. Several Semi-automatic and fully automatic segmentation algorithm where proposed for segmenting the retinal fundus image to extract blood vessel in the image [21]. Major algorithm which concentrate on the segmentation of blood vessel are listed as follow Graph cut technique, Graph Tracer algorithm, Morphological approach, Neural network in which Deep neural network, convolutional neural network, Hybrid neural network, octave convolutional neural network and Fuzzy-C Mean. Here graph cut and morphological approach are semi-automatic while other algorithms are fully automatic.
The structure of the paper include the section 2 segmentation of retinal fundus image using Graph cut and Graph trace algorithm, section 3 segmentation of retinal fundus image using morphological operation, section 4 segmentation of retinal fundus image using neural network, section 5 comparative study, section 6 conclusion.

II. GRAPH CUT AND GRAPH TRACE ALGORITHM

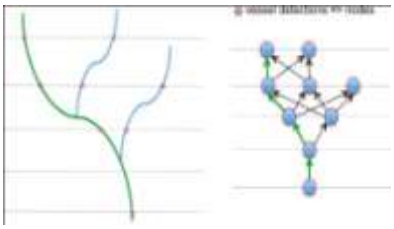
Segmentation of retinal image initially done by means of two approaches, one is pixel processing segmentation and graph tracking segmentation. In pixel based segmentation the energy of the neighborhood pixel is analysed and taken into region of interest (ROI). In graph based segmentation the initial seed point need to be provided. By tracking the energy level of the neighborhood pixel segmentation is done. Both pixels based and graph cut approach has its pros and cons. The pixel processing approach gives complete vascular information since it search all vessel pixel throughout whole image [2]. But the main drawback is taken more time to process the image and also it is expensive since it needs some extra hardware if the dataset is big. False detection of retinal blood vessel occurs if there is presence of noise and interference which lead to reduction in performance. Ana Salazar-Gonzalezet al (2014) [2] the tracking method provide ease of computing with accurate detection of blood vessel by tracing the blood vessel only through the detection of pixel value in the neighborhood of the vessel instead of processing whole image pixel value. Graph tracing is a semi-automated in which the manual input is needed from where the tracking has to start which is time consuming. Thus graph cut and tracking algorithm are proposed by several author Lekha.P and Sudha.K [3], Kota Prajwal Kant [4], Soumyashreekodliwad et al [5], AntoBennet.M et al[6].The flow of Graph cut algorithm is shown in Figure 1 (a).



(a)



(b)



(c)

Figure 1(a) Flowchart of Graph cut Algorithm (b) Retinal blood vessel arise from the optical disc (c) How tracing starts from the optical disc pixel is considered has node.

Lekha.P (2014) presented an algorithm based on graph tracing which identifies the retinal blood vessel by segmenting and representing by means of binary tree [3]. Two major approaches where utilised in crossover identification, first thing is crossover identification and second thing is obtaining vessel. Figure 1 (b) and Figure (c) shows how the graph trace algorithm works. Cross over can be determined from either crossover point or segment. Graph based approach provides the accurate result if the blood vessel flow parallel, if there is any bifurcation or cross point n between then the vessel, tracking will be done by analyzing vessel only near optic disc alone.

The segmentation of optic disc by graph cut segmentation is presented by [4] Kota Prajwal Kant (2016) which defines the optic disc location. Convergence feature of the retinal blood vessels near the optic disc is utilized in finding the optic disc location. The segmentation of optic disc is made by utilizing two distinct automatic techniques Markov Random field image reconstruction for segmenting and compensation factor for analyzing. [5] Soumyashreekodliwad (2016), Graph is made of several node and undirected edge. Here each pixel forms node in a graph and a set of undirected edges which connects the neighboring node. The tracking is done from source node to sink node through neighborhood node. Two types of link where used to connect the node n-links and t-links

The connection between the neighborhood node is done through n-link while source or sink node is connected using t-link. [6] AntoBennet.M (2016) the cross over blood vessel segmentation is discussed in detail.

III. MORPHOLOGICAL SEGMENTATION OF RETINAL BLOOD VESSEL

Morphology means structure from the name it is clear that the segmentation is based on the structure or shape present in the image. Dilation and erosion are the two main approaches utilised in morphological segmentation. Dilation deals with the thickening of object located in image. Erosion deals with the thinning of object located in image [7]. Accurate result is obtained by using morphological opening and closing of the image by structure detection. Dilated image is subtracted from the erosion image to get exact segment of object of interest [8]. For smoothening and noise removal morphological segmentation is used [9]. Opening and closing of image is taken into account. They utilized convolution metric to get linear structure of the retinal image for glaucoma detection. In supervised morphological segmentation there will be two images one is the original image need to be processed and second is set of pixel element, kernel. By applying kernel, dilation and erosion has performed. Top hat algorithm is used to segment the image based on its morphology [10]. From the whole information got from the above proposal the

morphological segmentation is an unsupervised segmentation. Figure 2 shows the flowchart of morphological segmentation of blood vessel in retinal fundus image. It is well suited for the diagnosis of diabetics or glaucoma. It is one of the automatic segmentation methods at the same time it requires training data to get accurate result.

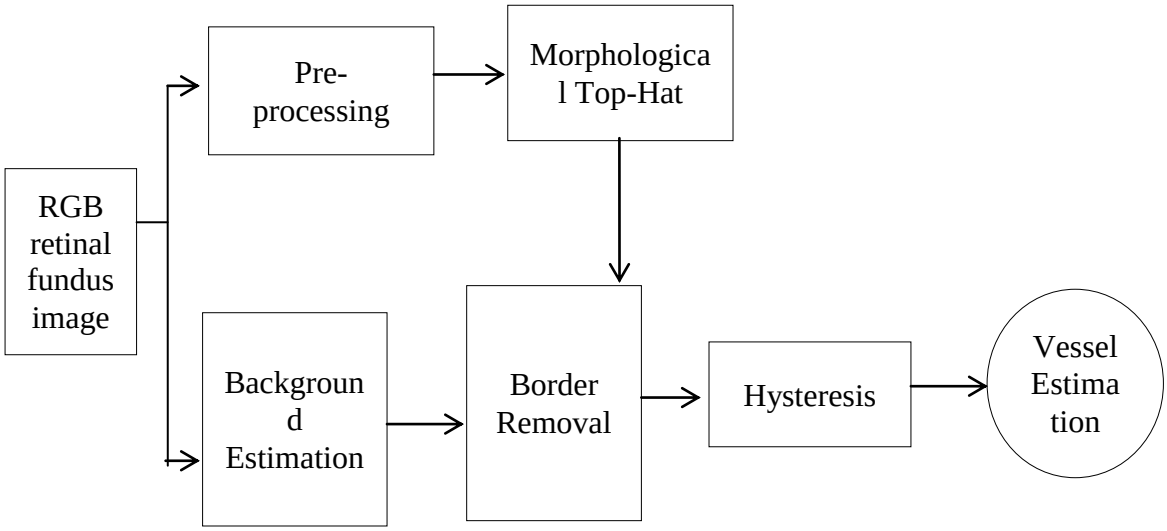


Figure 2. Morphological segmentation of retinal blood vessel

IV. NEURAL NETWORK BASED RETINAL BLOOD VESSEL SEGMENTATION

Fully automatic segmentation of blood vessel in retinal fundus image can be made by means of using neural network presented in [12]. Martina Melinscak (2015), neural network in combination with deep learning is proposed which utilize the U-net algorithm for segmenting artery and vein based on the brightness and intensity information. Fully automatic segmentation is done by utilizing CNN(Convolutional Neural Network). Here the MPCNN has three component [12] sequence of convolution, max pooling and fully connected layers. MPCNN map the input sample into output space through several layers which extract the feature and fully connected layer classify the extracted feature. Filtering is performed between the input image and convolutional layer. For doing segmentation, images are taken whose central pixel with its neighborhood need to be identified for differentiating blood vessel and non-blood vessel. Once blood vessel is segmented from the input image the feature can be extracted based on the requirement. [13] Give detailed benefits of fully convolutional neural network in fully automatic intensity based segmentation of blood vessel in retinal image for cardio vascular disease. U-net implementation is utilized for vessel extraction which accepts colour fundus image for analysis rather than gray scale image. In order to improve the performance of segmentation background homogenization is used. Blood vessel appearing darker than the neighbor is considered for the extraction of feature [19].

Supervised learning based segmentation of retinal fundus image is presented by MahoroAdidja [14].Where learning the input by comparing the input data with the trained dataset is said to be supervised learning. Supervised learning is a model which predicts the output based on the relationship between the input image and the trained image. Supervised algorithm for retinal image segmentation is to train a classifier on extracted feature by classifying the vessel or non-vessel. Some algorithm which are proposed for supervised learning are Bayesian classifier, Adaboost classifier, K-nearest neighbor classifier, support vector machine, neural network classifier. All supervised algorithm listed previously has their alone advantage and drawbacks. Accuracy in segmenting the retinal is prime factor need to be considered in analyzing the performance. DRIVE database is utilized for analyzing the accuracy of each algorithm and their performance comparison is presented in [14]. Though the accuracy of each algorithm is better, in order to improve the accuracy Nayak, presented combined curve let transform ad multi-layered thresholding. Even this approach gives high accuracy the process involve more time to segment an image.

Retinal vessel segmentation based on cascaded network presented by YanfeiGuo [15] He applied Bidirectional Symmetric Cascade Network (BSCN) in segmenting the vessel in retina. First step is fed the input image to scale detection segment which segment the vascular feature of vessel at various scale diameter of vessel, every segmented image contain two vessel prediction map, First map is taken from lower to higher and second map is taken from higher to lower. Finally the segmented blood vessel is taken

from fusion of vessel contour. Retinal vessel segmentation based on Bidirectional Symmetric Cascade Network (BSCN) involves three different special approach, First thing is segmentation is converted to scale detection, Second thing is Dense Dilated Convolutional Module (DDCM) which capture the very small, blur and less resolution information. At last vessel segmentation is done by Bidirectional Symmetric Cascade Network

Nasser Tamim et al [16] did research on modification in Multi-layer Perceptron neural network to obtain the blood vessel from the retinal image by eliminating the background pixel element. Instead of pre-processing, they used offset method to render a homogenous, uniform noise free image. Each dataset need to be evaluated and tested independently. Dataset also have some challenge like variety image dimension, illumination, number of available images etc. Modified MLP is one of fastest automatic segmentation method helps ophthalmologist by providing information about size, bifurcation, cotton wool spots, hard and soft exudates etc. This model needs further improvement to increase the accuracy in early prediction of disease. Another method neural network based segmenting blood vessel efficiently by using multi frequency convolutional network is presented in [17]. Zhun Fan et al built an octave convolutional neural network based on the UNet which extract the feature based on the multiple-spatial frequency and construct vessel segmentation maps [18].

IshmeetKaur et al presented fuzzy-C mean clustering and neuroscopic based unsupervised learning of retinal fundus image. The enhanced image is given has input to fuzzy-C mean clustering. Then the unsupervised learned data is segmented using neutrosophic approach which refines the segmented data into vessel, non-vessel and indeterminate sets. Accuracy and automatic fast segmentation is practically proven in this approach. Though neural network provide better performance than the other methods the time need to train the images are very high. Because of this it become not suitable for analyzing large number of image. To overcome this unsupervised learning technique is utilised which save time in analyzing large amount of images [11].

V. COMPARISON OF PERFORMANCE DIFFERENT RETINAL BLOOD VESSEL SEGMENTATION METHODOLOGY

The performance of different retinal blood vessel segmentation is analysed based on the accuracy as shown in Table 1. False detection leads to tremendous effects so accuracy, Sensitivity, Precision and Specificity in diagnosis is main criteria for analyzing the performance using the equations 1, 2, 3& 4:

$$\text{Accuracy} = \frac{(Tp+Tn)}{Tp+Tn+Fp+Fn} \quad (1)$$

$$\text{Sensitivity} = \frac{(Tp)}{Tp+Fn} \quad (2)$$

$$\text{Precision} = \frac{(Tp)}{Tp+Fp} \quad (3)$$

$$\text{Specificity} = \frac{(Tn)}{Tn+Fp} \quad (4)$$

Where Tp, Tn, Fp, Fn stands for true positive, true negative, false positive and false negative accordingly.

Table 1: Comparison of results in terms of Accuracy, TPR and FPR

Techniques mentioned	Accuracy	Sensitivity	Fall out (FPR)	Precision	Specificity
ElaheMoghimirad et al [1]	97.67%	84%	3%	-	96.32%
Ana Salazar-Gonzalez et al [2]	94.12%	75.12%	3.16%	-	96.57%
Soumyashreekodliwad et al [5]	91.15%	50%	5.18%	-	97.43%
D.SivaSundhara Raja et al [8]	95.1%	60%	4.6%	-	-

Gehad Hassan et al [9]	94.2%	45%	4.15%	71.36%	-
Manjusha S. Borse [10]	96.79%	65%	3.25%	64.56%	-
Martina Melinscak [12]	94.66%	72.76%	2.15%	-	97.52%
Ruben Hemelings et al [13]	96.98%	-	-	-	97.68%
MahoroAdidja et al [14]	93%	-	-	-	-
YanfeiGuo et al [15]	98.46%	78%	4.12%	81.23%	-
Nasser Tamim et al [16]	96.32%	60%	3.56%	82.15%	98.12%
Zhun Fan et al [17]	96.63%	-	-	83.25%	98.34%

VI. CONCLUSION

Several retinal blood vessel segmentation algorithms where discussed and compared based on the performance. These algorithms are applied and evaluated on publically available dataset drive. There will be no best algorithm based on performance metrics in segmentation of retinal blood vessel each has its own advantage and drawback on its own. Based on the application of study we can decide which algorithm is best based on accuracy, computational time and robustness. Automatic retinal blood vessel segmentations are needed for recent days since it will be useful for accurate and ease of recognition of pattern. Neural network based segmentation of retinal blood vessel are recently applied because of its automatic methodology. In real time application neural network based segmentation is highly used. In future a novel hybrid neural network based algorithm has to be formulated to improve the accuracy and timeliness.

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