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Retinal Blood Vessel Segmentation Using Supervised Classification

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ABSTRACT *:Retinal image plays a vital role in several applications such as reflecting the general state of the entire human body health. Automated retinal analysis has become an important screening tool in healthcare and an important step in the development of a computerized system for retinal analysis. Assessing their characteristics also plays an important role by providing useful information which helps in diagnosis, screening, evaluation, and treatment of ophthalmologic diseases at their early stages, such as diabetic retinopathy, hypertension retinopathy, glaucoma, age-related macular degeneration, and evaluation of various Cardiovascular diseases such as hypertension and stroke. The accurate segmentation provides the best contrast view traces of the retinal blood vessels, which might, therefore, be used to give an early and precise ophthalmologic disease for better diagnosis and treatment, by reducing human error and by saving time when a large number of images are acquired to be labeled. This work aims at reviewing the most recent and innovative supervised retinal blood vessel segmentation techniques on the basis of different classifiers such as Support vector machine classifier, neural network classifier, Bayesian classifier, Adaboost classifier,K- Nearest neighbor Classifier,Bayesina classifier, and other method used for giving an accurate segmentation of the retinal blood vessels network.*
Keywords: *Medical imaging ,retinal image,segmentation,supervised.*

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I. INTRODUCTION

The eye is the most important sensory organ of the human body which allows human to see and to interact with the diversity, for it is an indispensable mean of communication for human being in daily activities in term of perceiving beauty and connecting people with their surroundings [1],[2] .It also proved that is the only tissue in the human body from which the information of blood vessel can be unswervingly obtained [3].

The human eye is made up by 3 principal parts: outermost part composed by cornea and sclera, Middle part composed by the choroid, ciliary body, iris, and the innermost known as the retinal [4].It is the sensitive human cell which responds to the light and sends the signal to the brain via the optics nerves[5],however it is affected by different diseases such as diabetic retinopathy, retinal vascular diseases, macular diseases, cataracts and glaucoma[6], which are the main cause of blindness and lead to visual loss [7] .

By comparing the state of the retinal blood vessels, the eyes diseases can be detected as a leading cause of blindness induced by the alterations in the blood vessels of the retinal[8],Moreover, Detecting, diagnosis and controlling eyes diseases at an early age require the precise, and real information of the retinal blood vessels structure and having also knowledge of retinal blood vessels is helpful during any retinal surgery operations as well[9].

Several epidemiology studies prove that different types of diseases can be recognized by getting proper information about the retinal blood vessels, their anatomical structure and physiological homology between retinal and another human body system[10]. There is an association between retinal microvascular abnormalities, hypertension, cardiovascular disease and diabetes[11], in addition to that, retinal blood vessels offer clear advantages for cerebrovascular diseases screening, for they share many morphological and physiology properties with cerebral microvascular [12] , their damages also contribute to the pathophysiology of stroke, and its signs are linked to the risk of stroke as well [13] ,therefore, measuring the changes in retinal blood vessels, delineation of morphological attributes such as, color, length, reflectivity, tortuosity, abnormal

branching or occurrence of vessels of a certain width and having the proper information about the physiology of the retinal blood vessels is needed for helping in the identification of various diseases at an early stage [8].[14][14]

Manual detection of blood vessels is very difficult and time consuming because of the multifarious nature of the retinal vascular network, complexity and low contrast of the retinal vessels [14].The extraction done by physician manually consume more time accompanied by high mistakes due to dependency on the physician ‘s skills level The features extraction of retinal blood vessels from the retinal images necessitates using algorithm and instruments which reduce the dependency on the factor and eliminate the error factor[15],therefore partitioning a retinal blood vessel image into multiple segments represents a more meaningful image easy to analyze[16], and helps the physicians to diagnose, to treat and evaluate the progress of various disease. Most of those techniques use the green channel in fundus image as the first step of segmentation which provides the best contrast between the retinal blood vessels structure and the background [17].

Because of the multifarious nature of the retinal vascular network, several automated methods have been proposed to segment the retinal blood vessels from fundus images and use the most popular datasets in this field: (1) Digital Retinal Image for Vessel Extraction (DRIVE) ,which is a publicly available database, consisting of a total of 40 color fundus photographs,20 images for training and 20 images for testing. the photographs were obtained from a diabetic retinopathy screening program in the Netherlands,7 images of the 40 images in the database contain pathology, namely exudates, hemorrhages and pigment epithelium changes[16]. (2) Structuring Analysis of the Retina (STARE) contains 20 images for blood vessel segmentation; ten of these contain patholog [18]

These methods can be broadly divided into a rule-based technique and machine learning Method.The rule-based technique methods follow specific rules in an algorithmic framework and it is subdivided into kernel-based [19],[20],centerline tracking-based[21] ;mathematical bases [22]multiscale based [23], [24], [25];model-based [26], and adaptive thresholding approache [27],[28].

The machine learning method is divided into supervised and unsupervised. In the supervised method, prior information is used to determine a pixel as a vessel or not. During classification, user interaction is required to define the rule for each pixel/class or to provide the training data for each pixel or class when the Classifier is created based on training data from different classes.

In contrast, the unsupervised method performs the retinal blood vessels segmentation without any prior labeling knowledge where the classification identifies the pattern from the input dataset without predefined classification rules.It learns and organizes the information on its own to find the pattern or cluster that resemble the blood vessels [29].Moreover, the supervised have been shown to perform well on the problem of blood vessels segmentations [30][30][30], because they vary widely in their choices of features and type of classification used [31].

II. SUPERVISED LEARNING METHOD

Supervised learning is the machine learning methodology where the input data are mapping with a function to the target or to the output value by using the labeled training data. The supervised learning builds a model that can predict the output value and gives the input value based on the relationship between the input and the given correct output value [32].

The general idea about supervised algorithms for retinal vessels segmentation is to train a classifier on local or global extracted features by classifying whether the image pixels are vessels or non-vessels. Different authors have a different way of classifying the blood vessel segmentation, but the main idea remains the same .Most of the classifiers used for improving classification are Support vector machine classifier, neural network classifier, Bayesian classifier, Adaboost classifier,K- Nearest neighbor Classifier,Bayesina classifier [17].

II.1 Supervised Learning using Suport Vector Machine classifier

The support vector machine was proposed by Vatnik in the 1990s, as the new type of learning algorithm and the theoretical analysis tool to create practical algorithms for estimating multidimensional functions [33].

By combining two approaches for segmenting the retinal blood vessels, Sekulić et al proposed a method using support vector machine with the characteristic line detector, able to detect blood vessel of pathological and healthy person’s retinal images. Two features were suggested for performing the experiments, the inverse green channel and the continual line detectors, they were extracted from RGB retinal image by using the green channel . The inverse green channel scaled in the range [0,1] used for feature calculation where the value is calculated by subtracting the scaled green channel value from 1 ,whereas the continual line detectors used for calculating the average value of the line for 12 in different orientations for determining the strongest line detector.

The SVM was trained by using the Gaussian Kernel and used for classification as well. The proposed approach was trained and tested on the public database DRIVE and achieved accuracy of 94.3%. This achievable accuracy will be a benefit for enabling the system to detect the diseases presented in the image and possible categorization diseases within it. Petar Sekulićet al. [34].

As further for detecting the microaneurysm at an early stage, helping in turn as the first step of preventing Diabetic retinopathy, the segmentation of the retinal anatomical structure is important.

The retinal structure was segmented by using curvelet transform which represents efficiently the edges along the curves. The morphological operations detect Exudates and microaneurysm where the extracted structure of the images was examined with the structuring elements as a set of another known shape.

The feature extraction was done by considering the feature vector which consisted of 7 features: the area of blood vessels, area of exudates, area of MA, contrast, homogeneity, correlation, and energy. They obtained from the segmentation of retinal structure and Texture analysis which gives the information about how the surface pixel is arranged and their relationship with the surrounding pixels.

The Image pixels were classified by using SVM and the proposed method was evaluated on DRIVE and the accuracy was being up to 96% . Sayyada et al. [35]

By increasing the accuracy and efficiency diagnosis over a short period of time in detection of many eyes diseases such as hypertension, arteriosclerosis and the blindness that may be caused by diabetes Gabor wavelet and SVM method was proposed [36].

The method consists first by extracting and inverting the green channel ,where the blood vessels appear brighter than the background, and 2D Gabor wavelet transform for getting the significant information of the retinal image, As the retinal vessels structure is non-oriented, GWT was computed for θ to detect vessels in any orientation, GWT was spanning from 0-170 degrees.However, during classification stage, some errors might be caused by GWT computation, in order to avoid them and getting a good achievable classification, the normal transformation was applied to the feature extracted and SVM was used for segmentation and classification.

The Method was performed and tested on publicly available database STARE ,the measures was measured in term of accuracy 94.4% for normal image and 94,77% for an abnormal image. This lends a helping hand to an ophthalmologist to do the very accurate diagnosis on shot time

On another hand, Xu & Luo [37],proposed a method of segmenting the retinal blood vessels in order to overcome the variation in contrast of large and thin vessels, where the pixels attached to the large and thin vessels show different gray level and geometrical correlation with the nearby pixel during the acquisition process.

The method consists of extracting large and thin vessels separately and normalized the background by subtracting an approximate background from the original gray image obtained from the green channel.Thereafter, the adaptive local threshold is used to binarize the image ,where the large connected components whose areas are greater than the minimum grain size which are considered as large vessels candidates, however, the optic disk are usually mistaken for large vessels.By convoluted the gradient image with sober operator, the edge of the optic disk are erased automatically and the residual fragments of the binary image are not all considered as noises .

Some basic line detectors are used to identify the orientation of thin vessel for later classification, the feature was extracted by wavelet and curvelet transform, whereas the SVM is used for classifying vessels and non-vessels .

The method was evaluated on the publicly available DRIVE database and obtained the average accuracy of 93.2%

II.2 Supervised Learning using Neural Network

The neural network proposed by Warren McCulloch and Walter Pitts as the model of neurological networks in the year of 1943, and introduced in learning machine in 1965 by Nils Nilsson as the basic principle of self learning [38].

The neural network method for detecting and preventing microaneurysm as a key in detecting diabetic retinopathy caused by the Diabetics mellitus was proposed [39, 40].

The preprocessing consists of getting the image value intensity representation by converting the RGB image into HIS and by removing the vessel central light which runs down the central length of the blood vessel by applying Morphological opening operation .

For improving the performance of the vessel's segmentation, the process of background homogenization was considered. Using filtering operation with a large arithmetic mean Kernel for making the background pixel intensity on the same intensity . while the blood vessels appeared darker than their surroundings ,the image feature was extracted by using feature base, and classified by using neural network classifier, thereafter by adjusting the intensity of the image obtained after segmentation, this increase also the

contrast of the segmented image hence the microaneurysm structure was identified,The proposed method attained appreciable accuracy and is less computation time

In addition to that for early detection of some diseases by using a neural network approach, Diego et al proposed a method of segmenting the blood vessels in the retinal image, by using gray level image and moment invariant.

The method aimed by removing the Vessel Central Light Reflex, by applying a morphological opening using a three-pixel diameter disc, and by homogenizing the background with Filtering operation with a large arithmetic mean Kernel, while the Morphological Top hat transform is applied for vessels enhancement. For characterizing each pixel from a fundus image where it belongs to the real blood vessels or not, the combination of two different feature: gray level and moment invariant based feature were used and the classification is done by NN classifier.

Afterward, the classification was enhanced by filling pixels gaps in detected blood vessels and removing falsely detected isolated vessels pixels.

The method was tested and evaluated on a publicly available database of color fundus image DRIVE, in term of accuracy and the method proved accurate for vessels with the value of 94.52% which is effective and robustness tool for being integrated into a complete prescreening system for early detection [40].

II.3 Supervised Learning using Adaboost classifier

Lupaşcu et al presented the method where the classifier is trained on the gold standard example for vessels and non-vessels pixels, which in turn used for classifying the previous unseen images.

For this approach, the feature vector is constructed, encoding information on the local intensity structure, special properties and geometry at multiple scales.

The algorithm was tested on the public digital retinal image for vessels extraction (DRIVE) dataset with the achievement of an accuracy improvement of 95.97% which is beneficial for capturing a rich collection of retinal shape and structural information, Carmen [41]

II.4 Supervised Learning using K-Nearest Neighbor classifier

By detecting the development of abnormal new blood vessels in the retinal which is the main indicator of the major cause of blindness eyes diseases diabetic retinopathy, saranya et al, proposed the method to detect the abnormal new blood vessels by using the segmentation technic of Fuzzy C means.

The approaches consist of extracting automatically the blood vessels from green channel plane, normalize and enhanced the contrast of the image by adaptive histogram equalization, this, in turn, shows the best contrast between the blood vessels and the retinal background, Thereafter the obtained images were segmented by using Fuzzy C-Means Clustering Technique, where each point in an image belongs to two or more clusters with different degrees of membership. The features in the image that has close similarity were grouped into the same cluster, Features were calculated based on contrast, brightness and classified as normal and abnormal blood vessels by using K Nearest Neighbor (KNN) classifier.

The method was evaluated and tested on the DRIVE database and showed the best accuracy of 96.56% , capable of detecting very small blood vessels in the image [42]

II. 5 Supervosed method byusing Bayesian classifier

Fraz et al presented a blood vessels segmentation approach which used in the computer-based retinal analysis for importance detector of various clinical diseases and disorder of the eyes and the body.

The approach consists of segmenting the retinal vasculature from the ocular retinal fundus image, the retinal vessels manual segmentation is used to label the feature of the training image which in turn used to train a classifier.

The testing image was considered to generate the vessels feature, which applied to the previous classifier to compute the segmented vascular tree, furthermore, the 7-D feature vector constructed by computing the output of morphological linear operator, line strength measures of pixels and oriented Gabor filter at multiple scales. After getting the feature vector the Bayesian classier was used to classify the retinal image into vessels and non-vessel pixel.

The proposed approach was tested on DRIVE database and the experimental results obtained showed that the approach is effective as it achieved the average accuracy 94.76% which makes the proposed method a suitable tool for Diabetic Retinopathy, incorporation screening system to initially identify the normal retinal image [43].

III. OTHER METHODS

III. 1 Curvelet Transform And Multilayered Thresholding method

Nayak presented a method of Curvelet Transform and multilayered thresholding technique for retinal blood vessel, useful for detecting , segmenting and give the good accuracy of the retinal blood vessels from the retinal vasculature.

The method consists of converting the fundus image into the green channel image,the curvelet transform is used for image edges enhancement and making visible the thin and less visible vessels, Thinning operation which consists of making the output of edges detected more orderly by reducing all lines to single pixels. Thickness was applied for removing the selected foreground pixels from the binary image, the obtained edges were filtered to preserve only the true edges where all blood vessels were presented as only one pixel wide easier to analyze and show their different characteristics.

The application of multilayered thresholding technic was applied for eliminating the false edges due to break in vessels and small segmentation.

The method was tested and evaluated on the publicly available Database DRIVE and the method gives the good accuracy of 97.24% [44]

III.2 Gabor Filter with Systematic Threshold

Farokhian et al presented the method based on Gabor filter with systematic Threshold method for Retinal vessel segmentation .

The method aimed for capturing the efficiency edges of the retinal blood vessels, the optimal location, and changes in shape and in width of the retinal blood vessel by using Gabor filter for efficient detection of the blood vessels.

The vessels pixels were segmented by using Threshold method divided into 3 system manner composed by EER (equal error rate), TER (total error rate) for the accuracy maximization, all for the purpose of getting a systematic way of deciding an efficient threshold value which dictates the quality of the segmentation.

The proposed method was tested and evaluated on public available database DRIVE and the accuracy method indicates the best performance of segmentation in term of accuracy with the value of 93.66% [45]

IV. DISCUSSION

Different methods have been raised by different researchers and have been classified into different classes to get the better accuracy of the retinal image in a short time .

In this work, we discussed the supervised method which falls into any one of five classifiers: SVM classifier, NN classifier, Adaboost classifier, KNN classifier, Bayesian classifier and other methods which are including in supervise algorithm.

The accuracy of the segmentation process was considered as the performance measure because it gives good consideration to the overall correctness of the classifiers and of its essential of achieving more precise and efficient computer aided.DRIVE database was used as a well-considered and popular database in the field of retinal vessels segmentation, because of its good resolution of retinal fundus images and of its availability manual labeled ground truth images, and because of its composition of two useful sets: training and testing set.

Among all the cited above methods, the one which has the best accuracy of 97,24 % which proposed by Nayak [44],developed the technic of combining curvelet transform and multilayered thresholding .

Even though the technic shows the best accuracy it used different and long process which may cause the segmentation process to take a long time for providing the best accuracy when the images are in big number.

The next method that showed the best performance was proposed by Saranya [42], capable of detecting the small vessels in the retinal fundus image with the use of KNN classifier but the method require other combined technic for getting the best accuracy .

The SVM based approach proposed by Sayyada et al. [35]showed the best accuracy as well which marked SVM the best method because of its technical orthogonal transformation, which converts the set of observation of possibly variables that have mutual relationship into a set of values of linearly variables that do not have a mutual relationship.

Even though the neural network's methods showed the superior performance, but the time required to train the images are more and it cannot be applicable when the number of images is more for testing

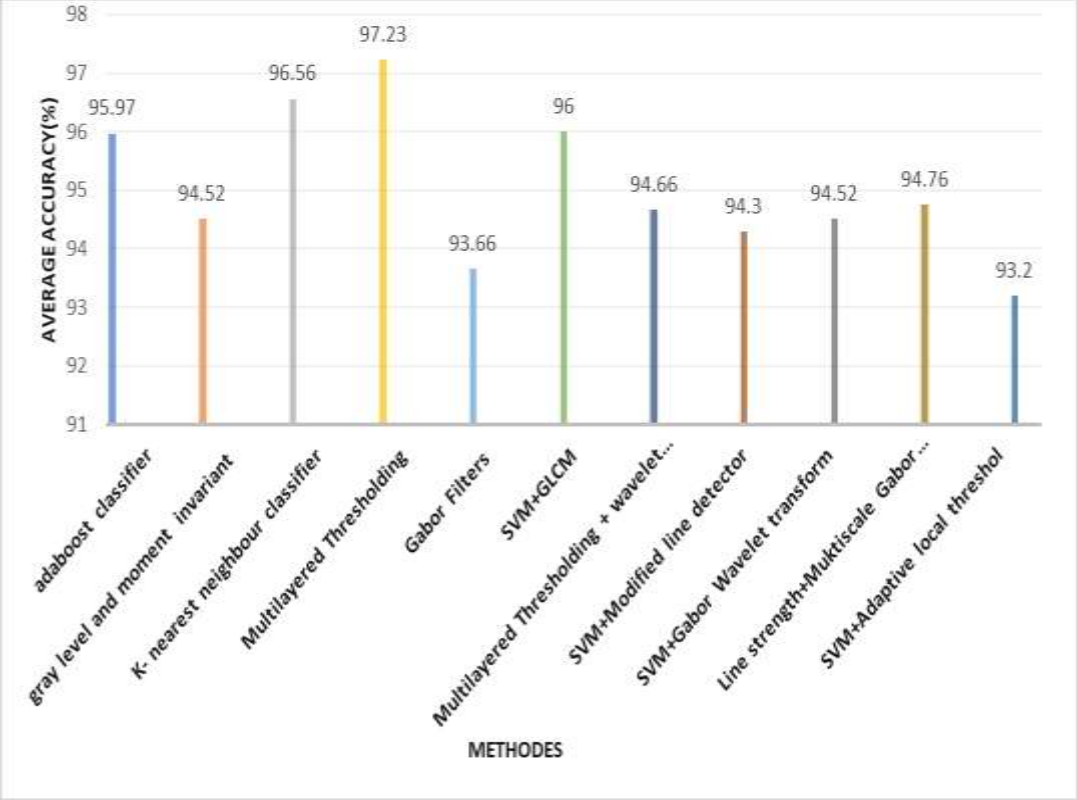

Figure 1. The average accuracy of DRIVE database

V. CONCLUSION

Automatic segmentation of retinal blood vessels is considered as the first step in developing a computer-assisted diagnostic system for the retinal image, many research articles have been proposed for retinal vessels segmentation for a helping hand to an ophthalmologist for doing very accurate diagnosis.

In this work most of the discussed technic used the grouping different method for getting the best accuracy result rate up to 93%, since all the methods used one classifier for classifying the pixels, the use of combined classifier is required for further improvements.

The discussed methods focused on early detection and diagnosis of ophthalmologic diseases. Whereas retinal vessels segmentation methods can be used for detecting others diseases related to brain and heart strokes, which are associated with the abnormal variations in retinal vascular structure and for cardiovascular diseases as it is bound on the blood circulation system, many types of research are required for further works. This work will help the researchers to select the most appropriate classification technique according to their requirements

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