Retinal Blood Vessel Segmentation Using PCA

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Abstract- The morphology of blood vessels in retinal fundus images is an important indicator of diseases like glaucoma, hypertension and diabetic retinopathy. The accuracy of retinal blood vessels segmentation affects the quality of retinal image analysis which is used in diagnosis methods in modern ophthalmology. In this project we are segmenting those retinal blood vessels of fundus images which helps the diagnosis of the eye related diseases. Through this blood vessel segmentation, the side effects caused due to the diagnosis of eye for different eye diseases can be reduced. In this project, we are performing the segmentation process by using PCA method. This paper proposes a three-step thresholding-based process to extract the blood vessels from the retinal fundus images. In the first step a unique combination of principal component analysis (PCA) and adaptive histogram equalization is used to enhance the retinal images. In the second step the blood vessels from the retinal fundus images are extracted by using the thresholding method. In the last step the morphological method is used to remove the unwanted pixels and the output segmented image is converted into a color image. In this paper we are using a DRIVE dataset to measure the performance of the proposed method. Our proposed method achieves an accuracy of 0.964, sensitivity about 0.624 and specificity about 0.991.

Indexed Terms- Blood vessel, fundus image, histogram equalization, morphological method, PCA

I. INTRODUCTION

Retinal imaging is a digital image captured of the retina, blood vessels and optic nerve positioned at the back of the eyes. This helps the optometrists to assist and cope various eye diseases such as, Diabetes, Glaucoma, macular degradation and hypertension etc. In fundus image analysis the automatic extraction of object from background is an essential task. But there are certain difficulties for this such as the variability in vessel width and low-resolution databases that includes noise and changes in brightness [1]. Many methods have already proposed for blood vessel segmentation by taking different databases which can be mainly categorized as: thresholding-based approaches, morphological approaches, unsupervised approaches, supervised approaches and model-based approaches.

In general, the thresholding methods are grouped as parametric and non-parametric approaches. In parametric methods, the probability density function values are appraised for modelling each class which is very exclusive and time consuming. Whereas the non-parametric methods, employs different criteria such as between class variance, entropy and error rate for quality verification of threshold values. Due to robustness and accuracy this can also act as an optimization function [2]. In [3], the author compared and developed different global thresholding-based method where the retinal images are pre-processed using phase congruency and contrast limited adaptive histogram equalization. In morphological based approaches, the vasculature shape is known priory. Then by utilizing different morphological operators the vasculature is segmented.

In [4], Fraz et al. employs a vessel detection method by using morphological bit plane slicing. Unsupervised approaches, depend on the fact that patterns belonging to the identical object tend to have like feature vectors and vice versa. In [5], the author, used matched filter with first order derivative of Gaussian to extract the blood vessels from background.

In supervised methods, vessels are classified either as vessels or non-vessels. Feature vectors extracted from training set of retinal images are used to train classifiers. Fraz et al. [6], introduced a supervised method for vessel extraction by using an ensemble classifier. Model-based methods put on explicit vessel models to segment the vessels [7]. In [8], the author introduced a method using level set and region growing to extract the retinal blood vessels.

From the literature, we noticed that many methods are existing for extraction of blood vessels. However, these methods are consuming more time and complex in nature. Therefore, the present investigation is focused to develop a suitable method for extracting the blood vessel with a view to minimize the time consumption and simple in nature due to easy implementation.

II. METHODOLOGY

Although many methods have been proposed to extract retinal blood vessels and also each published work gives better performance than other methods still the blood vessel extraction procedure is a challenging task. In this paper, we have proposed a three-step process where the first step includes pre-processing of the image using principal component analysis (PCA) and adaptive histogram equalization. The blood vessels are then extracted using thresholding method and then morphological method is used to remove the unwanted pixels in the segmented output.

A. Pre-processing

The steps followed in the pre-processing are discussed below:

1) Principal Component Analysis (PCA)

PCA is a method for compressing a lot of data into something that capture the essence of the original data. The graphical representation of PCA coordinates is shown in figure 1.

The PCA coordinates are defined from the original coordinates of the given input data. PCA determine these axes by maximizing the sum of squared distances from the projected points to the origin.

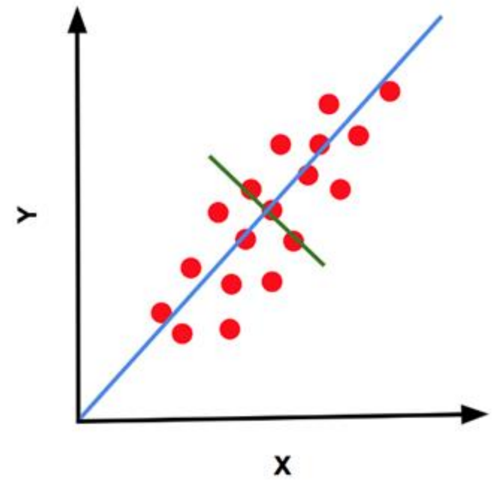

Figure 1. Graphical representation of PCA coordinates

PCA calls sum of the squared distances of the principal coordinate (PC) axis as Eigenvalue for PC and the square root of the Eigenvalue is called as Singular Value for PC. These two Eigenvalue and Singular value are determined for both the principal coordinate axes. With the help of these Eigenvalue of the coordinates variation for each axis is being calculated.

$$\frac{Eigenvalue\ of\ PC}{n-1} = Variation\ of\ PC$$

As mentioned in [9] PCA can be described as transform of a given set of n input variables of equal length formed in the n-D vector X into a vector Y.

2) Adaptive histogram equalization

In this paper as a part of pre-processing adaptive histogram equalization is performed to enhance the image for better extraction of the blood vessels from the input fundus images. With this the over strengthening of noise can be removed by limiting the contrast of the individual homogeneous section as discussed in [10].

3) Smoothing & background image extraction process

In order to remove the noise and smoothening the enhanced image an average filter is used and also background image extraction is performed.

To obtain the background image following steps are followed:

- A 9 x 9 box filter is generated.
- This filter is applied on the enhanced image to obtain the filtered image.
- The background image is obtained by subtracting the enhanced image and the filtered image.

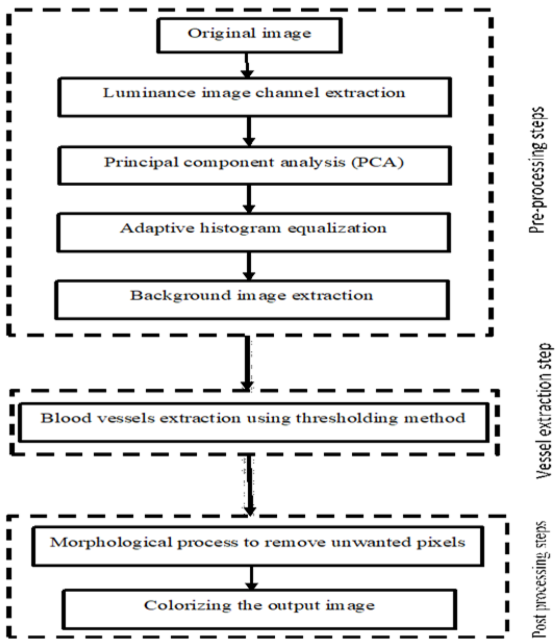

Figure 2. Block diagram of the proposed method

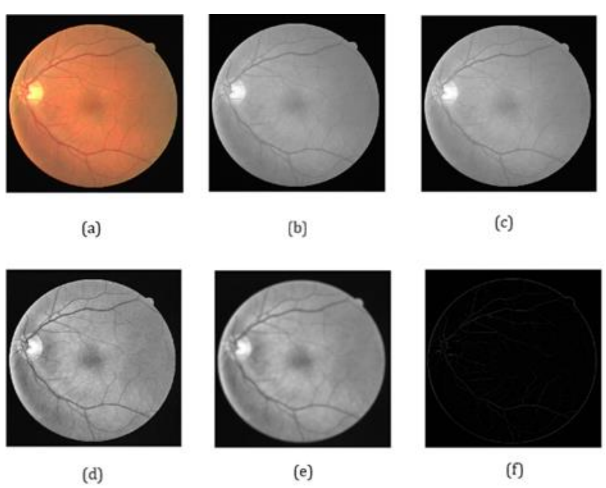

Figure 3. Pre-processing output images: (a) Original image, (b) luminous image, (c) PCA enhanced image, (d) Enhanced image output with adaptive histogram equalization, (e) Average filtered image, (f) background image.

B. Blood vessel extraction

In this paper, the blood vessel extraction is performed by the thresholding method. In our proposed method this thresholding is applied by calculating the histogram counts and bin number and using those two values the thresholding of the image which is being given as input to this thresholding function. In [11] the authors used global thresholding technique using Otsu method to extract the blood vessels. Our proposed method extracts the vessels way better than the Ostus's technique.

Figure 4. Output image after performing thresholding process

C. Post processing

From figure 4 it is clear after performing the thresholding process the output image might contain some unwanted frills. In order to remove those pixels, in our proposed method we are implementing morphological process on the image which is the output of the vessel extraction process step.

After cleaning the image, it is being converted into a color segmented image.

III. RESULTS AND DISCUSSION

The proposed method performance is evaluated with the help of DRIVE (Digital retinal images for vessel extraction) database.

The DRIVE database, [13] contains a total of 40 images and it is divided into training and testing folders and each folder consists of 20 images each. In training each image is provided with a mask image and a binary segmented image and in testing each image is provided with a mask image.

The ground truth image is compared with the output segmented image which is obtained through our proposed method to evaluate the performance of the proposed method. The pixels are classified as either vessel or non-vessel, so based on these two there are four possible ways to compare the images like true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The true positive is defined as if the pixel is identified as a vessel in the segmented image and in the ground truth image also if it is vessel pixel then it is known as true positive (TP). The true negative is defined as if the pixel is identified as a non-vessel in the segmented image and in the ground truth image also if it is non -vessel pixel then it is known as true negative (TN). The false positive is defined as if the pixel is identified as a vessel in the segmented image and in the ground truth image if it is a non-vessel pixel then it is known as false positive (FP). The false negative is defined as if the pixel is identified as a non-vessel in the segmented image and in the ground truth image if it is a vessel pixel then it is known as false negative (FN). For experimentation of the segmentation algorithms various mathematical measures are used which are represented in Table I. Sensitivity (*Se*), also termed as true positive rate or recall, that is it is the measure of the proportion of positives that are correctly classified as positives only. Specificity (*Sp*) is also known as true negative rate and it is the ratio of non-vessel pixels that are correctly identified as non-vessel pixels only. Positive predictive value (*PPV*) or precision is defined as the ratio of pixels identified as vessel pixels that are relevant. Negative predictive value (*NPV*) is the fraction of pixels marked as non-vessel pixels that are significant. Mathew's correlation coefficient (*MCC*) is the measure of quality of binary classification. It is a balanced measure which is applicable to classes of different sizes. It lies between +1 and -1 where +1 represents perfect prediction and -1 represents disagreement between prediction and observation [12]. Figure 5. Gives the output of the proposed segmentation methodology of DRIVE database. The average accuracy for the proposed method is 0.964 with *Se*, *Sp*, PPV, NPV, FDR, and MCC of 0.6245, 0.9918, 0.8604, 0.9703, 0.1396 and 0.7156 respectively for DRIVE database. We have compared our method with existing methods with taking different parameters such as sensitivity, specificity and accuracy. From TABLE II, we can conclude that our method gives better result than other methods and also the main advantage of our method is that it is very simple step process and takes very less computational time.

TABLE I. PERFORMANCE MATRICES

Parameters	Expression
se	$TP/(TP+FN)$
sp	TN/TN+FP
PPV	TP/TP+FP
NPV	FN/TN+FN
ACC	(TN+TP)/(TN+TP+FN+FP)
MCC	$\frac{(TP*TN)-(FP*FN)}{\sqrt{(TP+FP)(TP+FN)(TN+FP)(TN+FN)}}$
FPR	FP/FP+TN
FNR	FN/TP+FN
FDR	FP/TP+FP

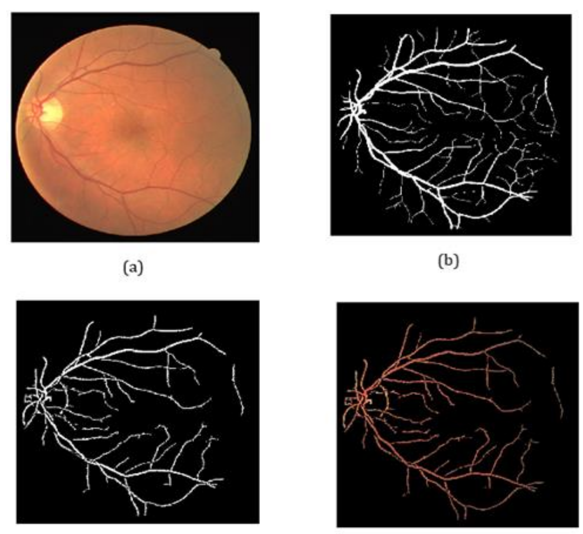

Figure 5. Output of the proposed method: (a) original image, (b) ground truth image, (c) segmented output image and (d) colorized segmented image

TABLE II. COMPARISION OF PROPOSED METHOD WITH OTHER METHODS IN DRIVE DATABASE

Method	Acc	Se	Sp
Fraz et al. [4]	0.942	0.730	.0974
Zhao et al. [8]	0.947	0.735	0.979
Zhang et al. [5]	0.938	0.712	0.972
Fraz et al. [6]	0.948	0.740	0.980
You et al. [7]	0.943	0.741	0.975
Proposed Method	0.964	0.624	0.991

CONCLUSION

In this paper we have presented a thresholding-based approach for extraction of retinal blood vessels. The combined use of principal component analysis (PCA) and adaptive histogram equalization for the enhancement of blood vessels gives a better enhanced image which is required before the segmentation process. The segmented image is converted into a colour image. The whole process is simple in nature and it requires very les time for execution. It achieves an average accuracy, sensitivity and specificity about 0.964, 0.614 and 0.991 for DRIVE database respectively.

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