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An Effective Segmentation of Retinal Blood Vessels using Optimized PCA and Morphological Operators

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Abstract—The structure of blood vessels interior in the eye is a significant source of indicator for many diseases if exist in a human body. The extraction of vasculature network of blood vessels which plays a vital role in the study and diagnosis of many eye related diseases like diabetic retinopathy, glaucoma, and many cardiovascular diseases is a challenging task. In this paper, a new method to derive tree-shaped vasculature from retinal fundus RGB images is proposed. This proposed algorithm is performed in two stages: (1) Pre-processing stage involves Particle Swarm Optimization (PSO) algorithm to compute optimized image which holds the global optimal pixels of the input RGB image followed by conversion of PSO optimized image to gray image using PCA which is then contrast enhanced with CLAHE. (2) Post-processing stage is carried out working on the contrast enhanced gray image for attaining better accuracy of retinal blood vessel segmentation by using Thresholding as well as morphological operator. The performance measures of proposed method are evaluated on DRIVE and STARE databases and obtained best results with an average accuracy of 96.44% and proven to be an outstanding method compared to other existing retina vessel segmentation algorithms.

Keywords—Retinal Fundus Image, Particle Swarm Optimization, Thresholding, Morphological Operator.

I. INTRODUCTION

The diabetic retinopathy is the most well-known cause for impairment of vision it causes loss of blood supply inside the retina by the broadly spread diabetes which leads to diabetic retinopathy [1]. The division of veins in the pictures of retina is a significant feature in diagnosis and treatment of diabetic retinopathy. There are numerous different illnesses that are frequently analyzed dependent on their progressions [2]. Retinal veins division is additionally the center stage in robotized enlistment of two retinal veins pictures of a specific patient to pursue and analyze his malady advance at various occasions [3]The classification issue of retinal veins division of each pixel in the field of retina is classified as vessel-like or non-vessel.

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The division of retinal vein is an extended monotonous assignment, in which the retinal veins division is a great deal of research in the satisfying picture handling territory since it is the basic segment of circulatory vein investigation systems [4].

The variation in the segmentation process of blood vessels and the quantitative measurement of retinal blood vessel plays a crucial role in many research efforts that are associated with vascular structures. Many clinical researchers proved that retinal blood vessels are significant structures of retinal images. in some cases, retinal blood vessel must be omitted for easy recognition of pathological lesions (exudates or micro aneurysms). The process of retinal blood vessel extraction practices few complications [5]: "(i) The retinal blood vessels have a wide scope of widths from (15 pixels) to (3 pixels) and different tortuosity. (ii) Various structures show up in retinal picture, as well as the optic plate, fovea, exudates and shade epithelium variations, which extremely disturb the programmed vessel extraction. (iii) The thin vessels with unlike surroundings may seem to be lengthened and disconnect spots, which are generally lost. (iv) The vessel power differentiate is feasible and variant, the tiny vessel is particularly overpowered. The figure-1 the diabetic retinopathy is identified by the clots of blood vessels in retina it causes when diabetic detects the tiny blood vessels inside the retina. Figure-1 gives an idea of the process of segmentation

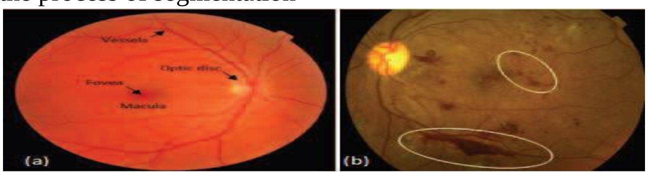


Figure-1(a) healthy eye(b) unhealthy eyewith leakagesin blood vessels

The remaining paper is arranged as follows: The section 2 introduces the related work that had done by different authors by using different optimization techniques. Section 3gives the flowchart and the algorithm of the proposed work followed by the explanation of the pre-processing step in Section 4 which includes finding global optimal pixels using PSO technique, conversion of the colored PSO image into gray using PCA, contrast enhancement of the gray image using CLAHE. In Section 5, the post-processing step is disclosing the explanation of usage of averaging filter to remove background of the image, computation of ISODATA thresholding, application of morphological operation. Section 6 gives the experimental results and discussions. Section 7concludes the work followed by list of references in Section 8.

II. RELATED WORK

Optimization techniques always have been a facilitator to move towards more efficiency and getting better accuracy in the effort of segmentation process. This section explains the work being done by various researchers by using different optimization techniques in their proposed approaches. The author in [6] combined Ant Colony segmentation results with Matched Filter to get better segmentation and proved that the approaches used in their work improved the accuracy rate and achieved an average accuracy of 0.9407 on DRIVE database and. The author in [7] used Genetic Algorithm technique for the optimization of appropriate matched filter parameters and this method achieved maximum average accuracy of 0.9422. The Particle Swarm Optimization technique was used by Thresiamma Devasia et al [8] in which they identified and segmented the optic disc and this method obtained 235 images which were tested on DRION dataset and their work proved that the identified optic disc centers had a constructive correlation. Kavya K et al [9] have used Fuzzy c-means clustering algorithm in which they combined each pixel in order to allocate their values in the respective clusters and the pixels that remaining separated among retinal pixels are optimized by using Bee Colony optimization technique and this method achieved an accuracy of 96.35% on DRIVE database. And the classification of this pixel is done by using Support Vector Machine based on their intensity level of damage in blood vessels. Nadaradjane Sri Madhava Raja et al [10] have used PSO based multilevel thresholding algorithm for the identification of tree like structures inside the retina and they extended their work by applying histogram equalization method during the pre-processing of the original image and then the segmentation process performed by applying Tsallis multilevel thresholding method and the result analysis of this method is done by using box plot representation it achieved an approximate mean value of 0.95% .

III. PROPOSED WORK

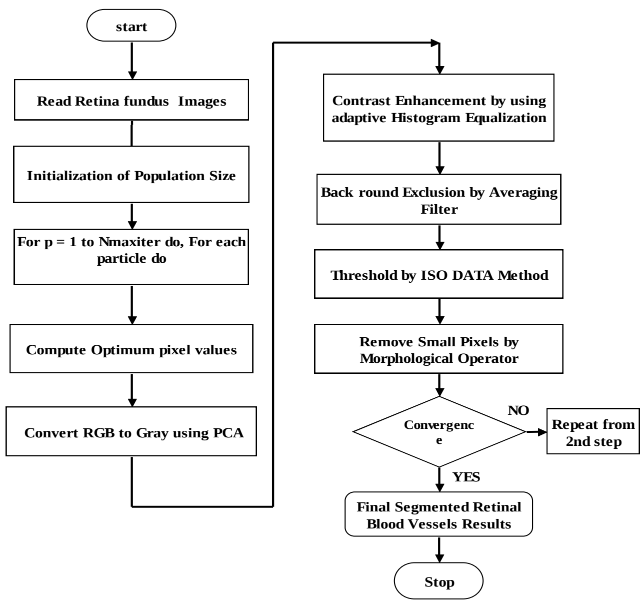


Figure 2: Flowchart of the proposed algorithm by using PSO initialization and Morphological Method

The above flowchart clearly depicts the approach being followed to segment the vasculature. To summarize the steps, first after the input RGB image is read, optimal pixels of the image is calculated using PSO with sufficient iterations. Next, mathematical technique named "Principal Component Analysis" is used to convert the PSO turned RGB image to gray image. Here, Principal Component Analysis extracts the blood vessel feature set and organizes them in order. Mask is applied upon to remove the background of an image.

The algorithm of the proposed technique is as follows:

Step 1 Read the retinal fundus RGB image as input

Step 2 Compute optimized image that contains global optimum pixels using Particle Swarm Optimization technique.

Step 3 Apply Principal Component Analysis to convert PSO image to gray image.

Step 4 Use Adaptive Histogram Equalization method that takes in gray image of step (3) as an input parameter to enhance the image contrast.

Step 5 Remove the background of the image using an averaging filter of 9x9 masks.

Step 6 Compute the subtraction of images achieved in step (4) and step (5) which is then used to find the threshold of ISO. This thresholding is then used as a parameter to binarize the resultant subtracted image of this step.

Step 7 Binarize the foreground and background as 1 and 0 respectively.

Step 8 By using morphological operators small image pixels are removed until the background condition of convergence fulfills.

The process of separating an image into a number of portions that share similar attributes is known as segmentation.

Based on intensity, color and texture of an image pixel is segmented and the segmentation of each image pixel focus up on their size, width and the direction of the vasculature as an unlimited goal. It uses green channel image because it enhances the contrast of retinal blood vessels from background where as the presence of the red channel images is saturated and the remaining blue part of the vision becomes dark. The primary indicators of the curvature of the Hessian matrix releases the occurrence of the proposed technique is preceded in two sections:

i The preprocessing stage includes finding the global optimal pixels using PSO technique which then followed by conversion of PSO image to gray image using Tyler Coye filter.

ii In next stage the input images are pre-processed for contrast enhancement of gray image in-order to achieve accurate results thresholding and Morphological operators are used.

A. Calculate optimum object pixels by using PSO

The creators of the algorithm by names Dr.Kenney and Dr. Eberhart (1995)[11] have intelligently pioneered by making drastic improvement in the procedure of PSO by means of conducting practical experiments upon schools of fish and groups of fowls. In this paper PSO technique is employed to find global optimal pixels. After the image is read for segmentation process, Then the PSO is applied with the parameters Moreover, PSO which is population-based algorithm possesses a pattern or a random probability distribution that is evaluated statistically leading to optimized solution but sometimes prediction may not be done precisely. In PSO, the basic assumption is that each particle of the population, which is randomly distributed in the search space, is taken as a solution initially. These particles which are called as potential solutions fly in the problem space by moving to the current optimum pixels that are nearer and neighboring pixel will have a tendency to move towards the best position depending upon their pixel position and its corresponding velocity. During this process every pixel fine tune its position to find the optimum solution focusing on its best position and distance from global best pixel position. In every series of the procedure, pixels that improve their existing positions are weighted through fitness function. The swarm is initialized with arbitrary particles as 'candidate solution' and it then looks for optima by modifying its position through iterations. During each iteration, PSO employs a fitness function that weights each pixel depending upon the two values p_best and g_best"

i "p_best" that defines the fitness of objective function as the best solution of every pixel attained for the moment.

ii "gbest' is that best solution that gets followed by every other pixel among the whole population.

The new position of each pixel is alteredbased on its new velocity with an equation.

$$V_{i+1} = w*V_{i(t)} + c1*r1(p\_best, i(t) - X_{i(t)}) + c2*r2(g\_best, i(t) - X_{i(t)}) \quad (1)$$

And it's new position then adjusted by using

$$X_{i(t+1)} = X_{i(t)} + V_{i(t+1)} \quad (2)$$

X_i, V_i represents the velocity and position of the i^{th} pixel.

PSO technique is employed to find global optimization pixels. After the image is read for segmentation process, PSO is applied with the parameters set as followed. Where $'c1'$,(local parameters) that represents the pixels that accelerate the local best position $'c2'$ (global parameter) that accelerates all the pixels to obtain global best position, With value 2 that communicates the pixels and swarm's fitness which handles equilibrium between each pixels best solution and global optimum solution along with properly chosen parameter so called as inertia weight $'w'$ which is a positive constant. Inertia weight's importance has been discussed in [12-17]. If we take $'w'$ as small, PSO turns out as local search technique which principles to an acceptable solution that is reachable to the initial space of search, and then PSO converges finding a global optimum sooner, if not optimization becomes difficult.If we consider it as large, then PSO turns out as global search technique which principles to optimum solution with number of iterations.

The below table determines the parameters being initialized to attain global optimal pixels.

Table I: Parameters of PSO

Parameter	Parameter Type	Values
C1	Local	1.3
C2	Global	1.3
r 1	Random value1	[0.1]
r 2	Randomvalue 2	[0.1]
w	Weight	1.9

B. Convert RGB to GRAY using PCA

Humans are aware of some color through wavelength sensitive sensory cells called cones which act upon the combination of three prime color intensities called red light, green light, and blue light. Cone stimulation is such a mechanism in human eye that encompass three types of cones that are able to generate any type of perceivable color. In computer language, gray scale images are characterized as integers. The luminance pixels of gray scale image ranges from 0 to 255. In MATLAB, an RGB image is a M*N*3 array of color pixel. In the same way, an array of a gray image is M*N whose values are scaled to signify image intensities. Most importantly, there is a function called rgb2gray () which is used for the conversion of RGB image to gray image. For preserving an RGB image, we would require 8(bits)*3(colors)=24bits. But, in RGB to gray conversion, only 8bits are required for the storage of a gray image.

In the process of converting RGB images to gray scale, the RGB values of each image pixel value is converted at location (i, j) to gray scale values by forming a weighted sum of RG/B color components and the same is allocated to the corresponding location (i, j) in new matrix which gives a single value pixel for every location in the output image.

C. AdaptiveHistogramEqualization

This method is used for the enhancement of an image and it also smooth's the segmented image in order to handle the unforeseen noise. The gray scale of an image is adjusted based on their probability distribution function of a particular image. It enlarges the dynamic range of an image in order to improve visual effects of a particular image for this histogram equalization conventional image enhancement algorithm is used. Irregular adaptive histogram equalization is known as contrast limited histogram equalization. it is an alternative to enhance contrast and it works on the small image regions. The output of the histogram approximately eliminates the boundaries. by using bilinear interpolation noise in the image is removed. The work done by [18-19] exposed that the usage of CLAHE which is based on local contrast enhancement when compared with other enhancement techniques they had got an optimal result. It is mostly applied on colored images.

D. Background Exclusion by Averaging Filter

The average of all the pixel values that replaces the center value is known as mean filter the noise in an image is reduced by using average filter. It is the only linear filter which supplies equal weight wk. to any or all neighborhood pixels. A weight of Wk.

= 1/(NM) is employed for associate N*M neighborhood. But in this paper 9x9 is used, it smooth's the image by substituting every constituent by the common worth of the intensities in its neighborhood. It is used as a filter to suppress the noise in a picture. It is wont to take away Gaussian noise with cheap impact. It's simple to implement. The average filters smooth and blur the pictures. the disadvantage of average filter is, it is not study to giant noise deviations within the image and once it straddles a foothold within the image it'll cause blurring.

E. Thresholding by ISODATA Method

Ridler and calvard developed an ISODATA methodology for computing image threshold which is used to alter an intensity image to binary image whose values lies between [0,1]. The foreground and background gray values are calculated, by average of these two means a new threshold value is calculated. The foreground images are segmented from background by using different segmentation techniques. It not only separates the foreground from the background but also recovers the superiority of the segmented results.

F. Remove Small Pixels by Morphological Operator

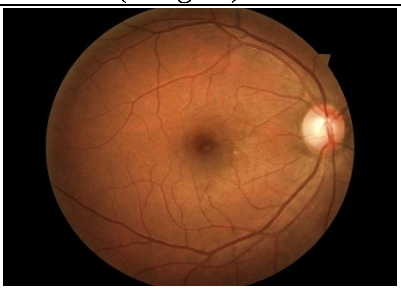
Morphology is a wide set of image processing operator that process images based on their shapes. To create an output image, the structuring element is applied upon input image by using MATLAB in-built morphological operator. The image pixels are removed based on their size and shape of the structuring element [20]. Morphological operators are generally used on binary images for background subtraction. The most basic morphological operations are dilation, which induces pixels in the required positions of the image and erosion, which removes pixels on the given criteria. The important segment of the erosion or dilation morphological operation is the usage of structuring element that focuses on each pixel and proceeds to describe its neighborhood for processing of that pixel. This structuring element, which can be either 'flat' that act on binary images or 'non-flat' that act upon gray image, is a matrix that depends upon the shape and size of the input image's object. In this proposed work, erosion operation has been used with '*structuring element*' parameter as the binary image which is the output of ISO Data Thresholding method been discussed above and the other parameter called '*structuring element offset*' as length 50 to prune small-sized blood vessels of size 50. The mathematical formula for the morphological opening is given below in equation (11) which is the calculation of dilation from the calculated erosion upon a set of 'A' by using a structuring element (SA) 'B' which is defined as

$$AoB = (A \odot B) \oplus B \qquad (3)$$

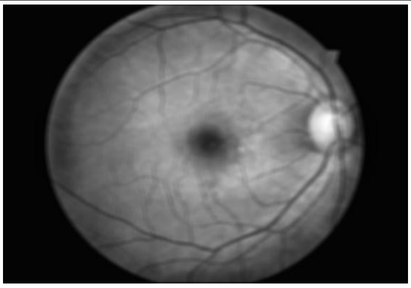
This operation produces an efficient segmentation of blood vessels giving an accuracy of 96.44%.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Column-1 (Image 1)



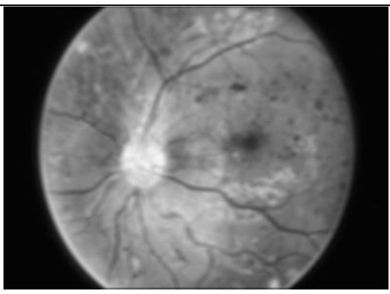
original Retinal Fundus Image



Optimized Filtered Image

Column-2 (Image 2)

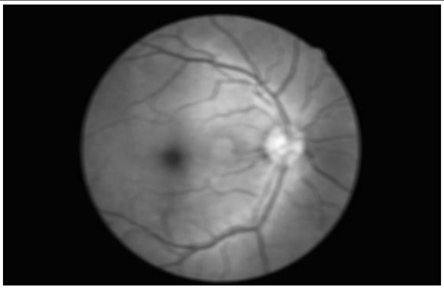
Original Retinal Fundus Image



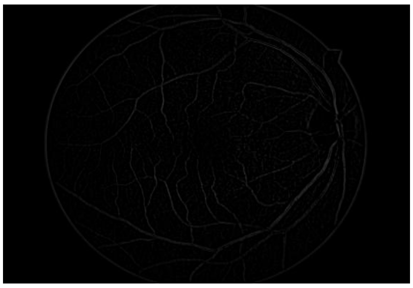
Optimized Filtered Image

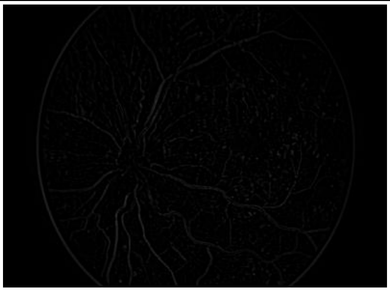
Column-3 (Image 3)

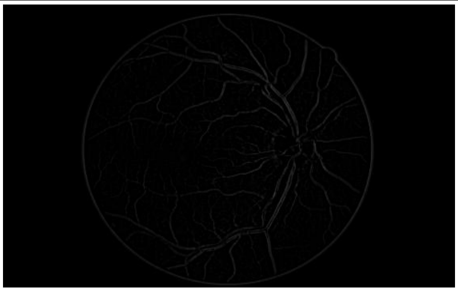
Original Retinal Fundus Image

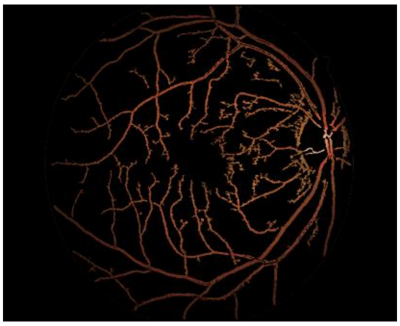


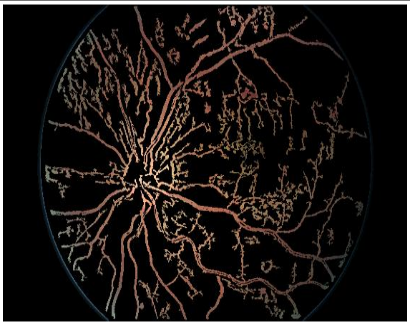
Optimized Filtered Image


Subtracted Image between Gray image and Filtered Image


Subtracted Image between Gray image and Filtered Image


Subtracted Image between Gray image and Filtered Image


Proposed Segmented Result


Proposed Segmented Result

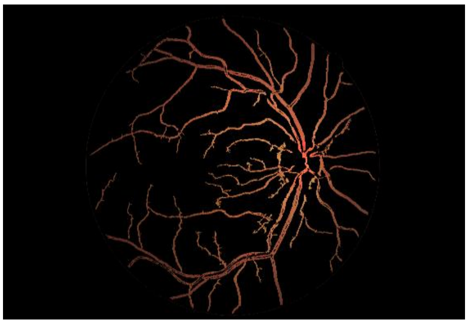

Proposed Segmented Result

Table II: Performance table of proposed segmentation method over ground truth

Images	Sensitivity (%)	Specificity (%)	Accuracy (%)	Ground Truth (%)
Image1	71.72	96.87	95.00	96.78
Image2	78.54	98.23	96.47	98.34
Image 3	56.85	99.21	97.87	98.76

A. Performance measures:

The outputs of the proposed work and their ground truth measures are the typical manual annotations that are mentioned by different ophthalmologists. These are specific for a particular database that evaluates the segmentation performances of the automated retinal image investigation values by means of sensitivity, specificity, precision accuracy and the f1- score which are based on the following aspects.

1. true positive (TP gives pixels which are correctly identified),
2. false positive (FP gives pixels which are incorrectly identified),
3. true negative (TN gives pixels which are correctly rejected), and
4. false negative (FN gives pixels which are incorrectly rejected*)*

where one can derive the following measures:

$$\text{Sensitivity} = \frac{TP}{(TP + FN)} \qquad (4)$$

$$\text{Specificity} = \frac{TN}{(TN + FP)} \qquad (5)$$

$$\text{Precision} = \frac{TP}{(TP + FP)} \qquad (6)$$

$$\text{Accuracy} = \frac{(TP + TN)}{(TP + FP + TN + FN)} \qquad (7)$$

$$\text{F1-score} = \frac{2TP}{(2TP + FP + FN)} \qquad (8)$$

The results disclosed in this section which are arranged in three columns for three images show the process of the method leading to effective segmentation. Also, Table 2 describes the performance measures which are calculated to make evident that the proposed method is quite near reachable to the ground truth segmentation and is outstanding with:

i. an average sensitivity of 69.03%(sensitivity is inversely proportional to better segmentation of blood vessels)
ii. an average specificity of 98.10% (the more value of sensitivity, the better segmentation of blood vessels)
iii. an average accuracy of 97.96% (the more value of accuracy, the better segmentation of blood vessels)

V. CONCLUSION

The effectiveness of using Particle Swarm Optimization technique is witnessed in this paper which gave an outstanding accuracy of the segmentation process. Also, the mathematical technique called Principal Component Analysis served a better purpose in getting the blood vessels column vectors as feature set which in turn has been instrumental in the process of conversion of color image to gray image. The result analysis being done proves that this approach which used DRIVE and STARE datasets gives better segmentation accuracy of 96.44%.

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