Optimized Technique for Detection of Diabetic Retinopathy using Segmented Retinal Blood Vessels

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***Abstract*—This paper presents an algorithm that will segment the retinal blood vessels with an accuracy of 96.17%. This algorithm will extract the features from input images present in STARE and CHASE_DB1 databases. The extracted features will be large in number but all the features are not useful. So, the feature optimization is done by Lion Optimization which has effectively chosen only the features which are useful in representing the extracted features as blood vessels or non-blood vessels. The algorithm was applied first on training images which have results of manually segmented images already. Then the algorithm was implemented on training images and evaluated on training images and it successfully detects the normal as well as abnormal images. The quantitative results were checked using parameters sensitivity, specificity, accuracy, positive predictive rate and false predictive rate and proved to give better results in comparison to existing techniques.**

***Keywords—Retinal blood vessels; CLAHE; feature extraction; Lion Optimization; accuracy*.**

I. Introduction

The retinal blood vessels when segmented accurately, helps in automatic detection of diabetic retinopathy retina. This can be done by the extraction of attributes like length, branching pattern, width etc of retinal blood vessels. If the retina of the eye is affected by any of the eye diseases such as Diabetic Retinopathy [15], then all the attributes of the retina shows morphological differences from the standard shapes and thus helping in disease detection. The other important parts of the human eye are named as optic nerve, central artery and vein, macula. Other applications of segmentation of blood vessels include biometric identification, image registration, localization of fovea etc. It is common assumption by all the ophthalmologists that the quantification of blood vessels into retinal and non vessels is the most important step in automatic detection of various eye diseases. The successive stages of diseases can be detected by identifying the valuable information of the vessels in retinal fundus imaging [17]. The major cause of blindness in India as well as in the world is Diabetic Retinopathy (DR) which prevails in the patients suffering from prolonged diabetes. The patients can only escape from these all diseases if they go through periodic examination of their eyes [2]. The various symptoms of diabetic retinopathy include the formation of microaneurysms, leakage of lipids and proteins from blood vessels leading to formation of exudates, hemorrhages and blockage in eyes.

DR is the dangerous disease as it is in progressive category of diseases and the symptoms may not be noted first. But with time, the symptoms get worse and lead to vision loss. Early diagnosis is required as the disease can be cured easily if the screening is done well on time.

In emerging time of computer aided diagnosis, the accurate segmentation of blood vessels helped ophthalmologists in diagnosing various eye diseases. The blood vessels as well as the pathologies present in the eyes can be easily detected after their accurate segmentation. If the pathologies or symptoms of the diseases are near macula, then it needs immediate attention and aid. If the pathology or any symptom of DR is close to macula, the more severe is the disease [16].

It will be very tedious task, if segmentation is done manually. So, there is need of automatic segmentation of retinal images. Many researchers have given number of these methods but still there is some space for new algorithms through which we can achieve high accuracies [17]. All the work can be evaluated on publicly available databases of retinal images. Various databases are DRIVE (Digital Retinal Images for Vessel Extraction), STARE, ARIA Online, CHASE databases etc. Figure 1 shows the normal as well as abnormal image of STARE database.

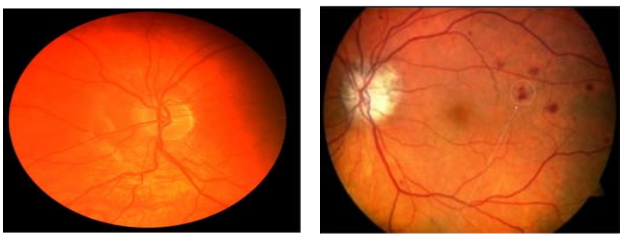

Fig. 1. (a) Normal Image; (b) Abnormal Image

Section I contains the introduction of blood vessels segmentation as well as of Diabetic Retinopathy and all the publicly available databases, Section II contain the related work about the various techniques of retinal blood vessels segmentation, Section III contain the proposed algorithm based on feature extraction and feature optimization by Lion optimization, Section IV describes results and discussion using parameters given by sensitivity, specificity, accuracy, false positive rate and positive predictive rate and Section VII concludes research work with future directions.

II. Related Work

The segmentation techniques for retinal vessels are categorized into categories given by Pattern Classification and Machine learning which is further classified into supervised and unsupervised methods, matched filtering, morphological processing, vessel tracking/ tracing, multi-scale approaches, model based approaches. The various latest approaches that helps in detection of DR includes an hybrid approach of wavelet transform and feed forward neural network under the supervised method category given by Chatterji et al. [11] images are segmented using wavelet transforms and then the system is trained using neural network to classify the pixels into correct category of vessels. Nadjia et al. [10] segments the image by using local properties of image based on Gray level Spatial Correlation (GLSC). Further, the vessel structures were enhanced by Yang et al. [12] by using hessian based filter and walk algorithms. Linear features were used by Vahid et al. [13] to detect vessels in both normal and abnormal images. Chakraborti et al. [14] developed matched filter method which achieved high sensitivity and specificity. Edward et al. proposed a multilayer perceptron neural network for automatically segmentation and detection of various eye diseases. Chaudhuri et al. [1] proposed matched filter method which helps in segmenting the vessel images in each and every possible direction using 2-d rotated templates of every image. Panas et al. [2] proposed an unsupervised category method using fuzzy algorithm which will trace the vessels and then classifies them using fuzzy C-means clustering algorithm.

Different classifiers were used by different researchers after the training of the system for classification of test images. Niemeiger et al. [4]used feature vector of 31 dimensions and KNN for classification and achieved accuracy of 94.16%. Bayesian classifier was used by Soares et al. [5] and achieves accuracy of 94.66%. Staal et al.[3] used k-nearest neighbor classification method which achieves accuracy of 94.41%. Marin et al. [6] used classifier based on neural network in addition to 7 dimensional feature vector for accuracy of 94.52%. Franklin et al. [7] used the intensities of RGB channels in addition to existing work and achieved accuracy of 95.03%. Xu et al.[8] used SVM for classification of in the image. Hassanien et al. [20] presented a localization approach for retinal blood vessels based on Artificial Bee Colony (ABC) swarm optimization. Bao et al. [19] presented a novel technique to segment the retinal blood vessels based using cake filter.

III. Proposed Algorithm

The proposed algorithm gives an optimized technique to segment the retinal vessels and therefore, helps in detection of various eye diseases especially helps in detection of Diabetic Retinopathy. This algorithm was evaluated on images present in STARE and CHASE_DB1 database. STARE database consists of 20 raw images from which 10 images are of healthy retina and the rest images are of pathological retina. It also consists of manually segmented images of two different observers. Automated segmented images are compared with the ground truth images for the evaluation of performance parameters. CHASE_DB1 is a database that consists of 28 images of 14 children as depicted by its full form that is Child Heart and Health Study in England. It also consists of manually segmented images by two different observers. Both databases contain images of healthy as well as of pathological retina which helps in evaluating the proposed algorithm accurately.

The methodology used to implement proposed algorithm used the following steps:-

Step 1:- Preprocessing of the Input Image:

Since the original image contains noise, uneven illumination and other problems, so the first step of segmentation algorithm is pre-processing. This step helps in making the input image more appropriate for the segmentation process. Also, the RGB image needs to convert into gray scale image so that the proposed algorithm can give good results. The various steps performed in pre-processing of RGB image includes:-

- *Extraction of Green Component from RGB Image:* - The input image consists of three channels as according to every RGB image, but, the green channel contains the maximum information and highest contrast regarding to blood vessels. The input image along with its different channels is shown in Figure 2.
- *Conversion into gray – scale and filtering of image:* - For decreasing the complexity of the image, the pre-processed image is converted which also increased its ability for segmentation. As the input image has uneven illumination and have noise, so some filtering is required for removal of noise. The image shown in Figure 3(a) is after conversion into gray scale and Gaussian filtering.
- *Contrast Enhancement:*-The contrast of the image is further enhanced by CLAHE method which increases the dynamic range of the image under consideration. After the process of pre-processing, the input image is suitable for further segmentation process [9].

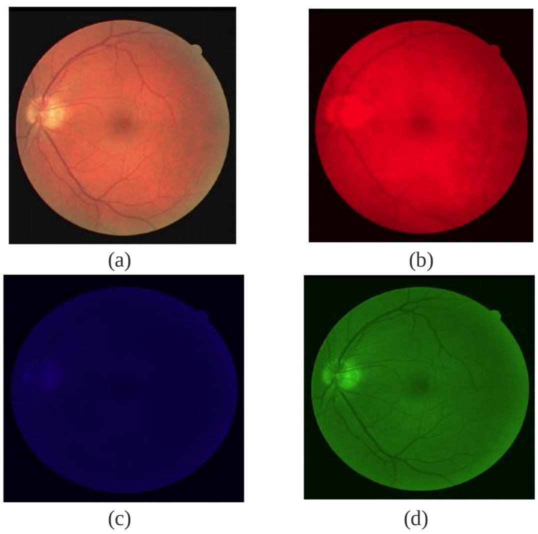

Fig. 2. a) Original RGB; b) Red Channel; c) Blue Channel; d) Green Channel

Step 2: Detection of Edges and Feature Extraction

The edges of the retinal vessel images were detected using canny edge operator. Canny edge detector helps in identifying the boundaries of the blood vessels. Gaussian filter is used to smooth the images by eliminated the noise. Then all the regions with high spatial derivatives are highlighted. As the edges of any image are the points having the maximum strength, so all the points on the edges are highlighted after the application of Canny operator on the retinal image. All other points that are not on the edge are set to zero.

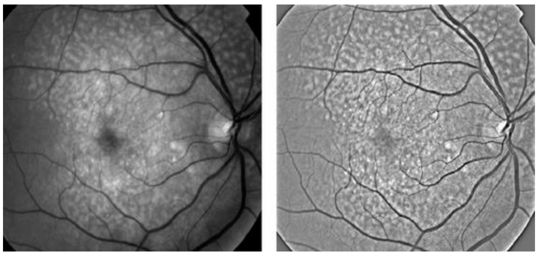

Fig. 3. (a) Image after Filtering; (b) Image after Enhancement

Every image is made up of number of features from which some features are useful in image description and others are not useful. The percentage of redundant data is also very high in each image. So, there is strong need of extracting the useful features from both normal and abnormal images and make a feature vector of selected features for segmentation of retinal fundus images. In the proposed work, feature extraction is done by PCA (Principal Component Analysis)[9] which helps in extracting the features from both normal and abnormal images. Only those features are selected from the extracted features which define the blood vessels and can help in classification of pixels as vessels and non-vessels. Feature vector is defined using the selected features only. Figure 5 and 6 shows the plot of feature vectors for healthy as well as for pathological retina.

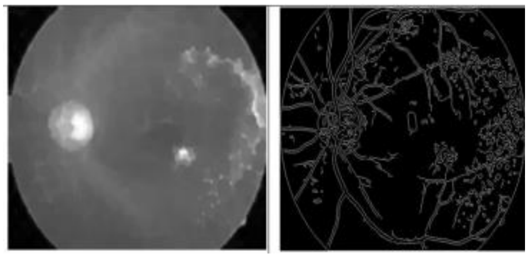

Fig. 4. RGB Image and the result after application of Canny Operator

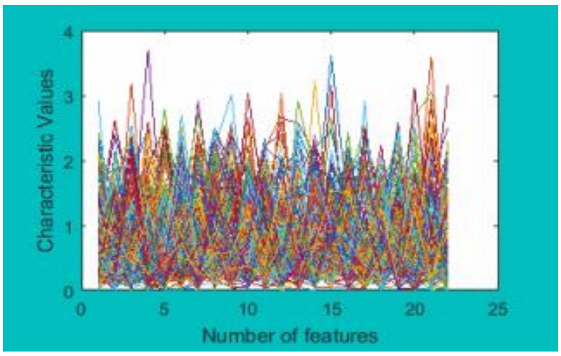

Fig. 5. Plot of Feature Vector for Healthy Retina

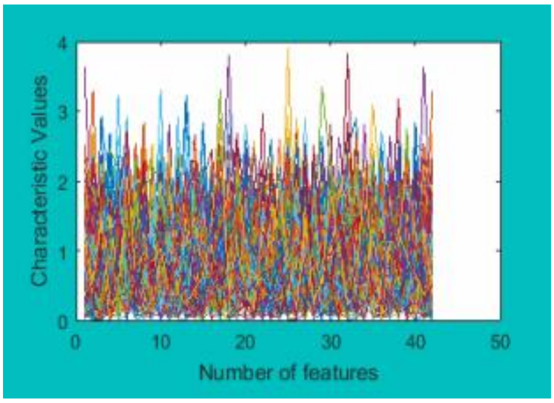

Fig. 6. Plot of Feature Vector for Pathological Retina

A. *Step 3:- Feature Optimization*

Feature optimization is used to find the optimum set of features to be given as input to the classification process. This optimization process was done by the Lion Optimization Algorithm [18]. It is based on the lifestyle of lion and their basic characteristic of cooperation. The unique characteristics of lions that make this optimization unique include style of capturing of prey, migration, mating, fighting with individuals, cooperative behavior of lions etc. The cooperation of lions is shown by the feature that they hunt together with their pride which increases the probability of success in these cases.

So, in this feature optimization process, when lion optimization was used, it gives optimized number of features as results which can be given to classifier for classification process.

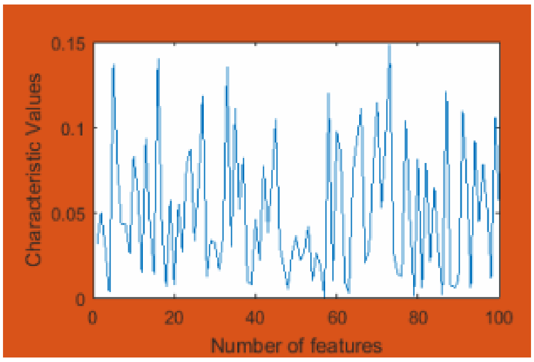

Fig. 7. Optimization Plot after LOA

B. *Step 4:- Feature Classification*

In this process, Naïve Bayes Classifier was used for classification process. Since the system knows which features to be considered for classifying the images into normal and abnormal images, so, it will work on testing database. It will give as output the pixels as retinal vessels and non retinal vessels and then classify the image as normal and abnormal image. That is whether the image has symptoms of Diabetic Retinopathy or not. All the false vessels will be removed and true vessels will be there for recognition purposes which will increase the recognition rate and accuracy. Naïve Bayes classification process is based on Bayes theorem. When the dimensionality is high, that is if the features are high, then this classification process is used. The process is classifies the pixels as true and false based on maximum likelihood. The advantage of this classification process is that it requires small amount of training data. Figure 5 shows the classification of normal images that is images that do not show any symptom of diabetic retinopathy as normal image. Similarly, images are classified as abnormal images also.

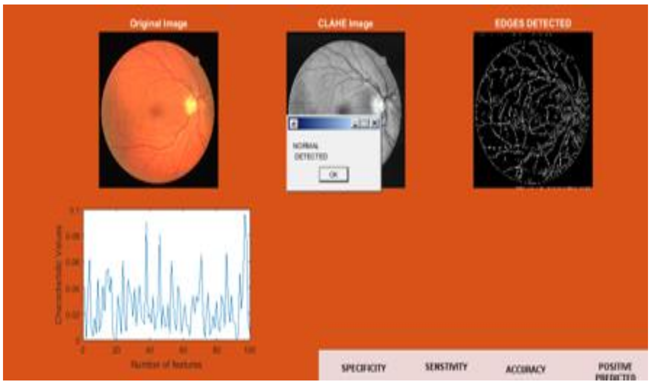

Fig. 8. Normal image is detected as normal after classification process.

IV. Results And Discussions

The objective evaluation was done by calculation of performance metrics like Sensitivity, Specificity, Accuracy, Positive Predictive Rate, False Positive Rate.

The values of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) need to be evaluated for these parameters [17]. The total count of pixels which are retinal vessels in both ground truth as well as in proposed algorithm will lead to value of TP. TN is the same case but for non retinal blood vessels. If the pixels are identified as blood vessels in ground truth images and but as non retinal blood vessels using algorithms will lead to increase the number of FP and the vice versa case is for FN.

Accuracy (Acc) is defined as ratio of sum of TP and TN to the total number of pixels. Sensitivity (Sens) is defined as the capability of the algorithm to detect the true vessels. Specificity (Spec) is defined as the capability of the algorithm to identify the false vessels.

TABLE I. PERFORMANCE PARAMETERS

Image	Table Column Head				
	Sens	Spec	Acc	PPV	FPR
1.jpg	94.34	96.88	5.54	98.64	97.44
2.jpg	88.22	98.65	97.44	99.34	98.45
3.jpg	91.01	99.88	95.76	96.12	95.12
4.jpg	93.22	96.12	96.88	89.56	88.34
5.jpg	92.11	97.44	94.64	94.67	93.45
6.jpg	89.1	88.44	96.67	97.75	96.67
7.jpg	91.12	97.22	95.12	95.56	95.89
8.jpg	93.67	98.33	97.99	94.87	97.88
9.jpg	88.54	97.25	94.22	89.91	90.1
10.jpg	92.1	98.98	97.44	93.12	92.12
Avg	91.34	96.91	96.17	94.9	94.54

The table I shows the final average values for all parameters that have been computed for evaluating the performance of proposed algorithm. Overall sensitivity is 91.34%, specificity is 96.91%, Accuracy is computed as 96.17%, Positive Predictive Value is evaluated as of 94.90% and false predictive value is evaluated as 94.54%. The main concern of any algorithm is the value of accuracy which gives the value how the automatically segmented value is near to the manually segmented value.

Table II contain the comparison of Human Observer and proposed system for the values of Sensitivity, Specificity and Accuracy. Sensitivity is less in proposed system but the accuracy and specificity have the higher values. Accuracy is the major concern as it will help in the detection of eye diseases very effectively.

TABLE II. COMPARISON OF HUMAN OBSERVER AND PROPOSED SYSTEM

Technique	*Sens*	*Spec*	*Acc*
Human Observer	93.24%	95.12%	95.76%
Proposed System	91.34%	96.91%	96.17%

V. Conclusion And Future Scope

This paper proposes a technique for segmentation of retinal blood vessels which uses lion optimization for the optimization of extracted features. The images are preprocessed using CLAHE. This method is helpful in detecting the location of pathology which helps in starting the treatment of patient. Features are extracted using PCA and then the extracted features are optimized using Lion Optimization process. Then the optimized features are used for training of the system and final classifying the images using Naïve Bayes classifier for the classification of images into healthy as well as pathological retina.

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