Segmentation of Retinal Blood Vessels using Lion Optimization for detection of Diabetic Retinopathy

Sukhpreet Kaur[1], Dr. Kulwinder Singh Mann[2]
[1]*Research Scholar, IKG Punjab Technical University, Kapurthala*
[2]*Professor, Guru Nanak Dev Engineering College, Ludhiana*

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 of both normal and abnormal images from DRIVE database. 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 pixels as vessels and non-vessels. The algorithm was applied first on training images which have results of manually segmented images already. Then the algorithm was tested on testing 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 be given better results in comparison to existing techniques.

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

I. INTRODUCTION

The segmentation of retinal blood vessels helps in automatic detection of diabetic retinopathy retina. This can be done by the segmentation of blood vessels of the retina for the evaluation of attributes like length, branching pattern, width etc. If the retina of the eye is affected by any of the eye diseases such as Diabetic Retinopathy, Glaucoma, Retinal Vein Occlusion, Retinal Artery Occlusion etc,[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-retinal vessels is the first step in automatic detection of many 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, hard and soft exudates, hemorrhages, cotton wool spots, lesions 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.

Due to this help given to ophthalmologists, retinal vessel segmentation becomes an important tool for recognition of various diseases. Segmentation also helps in detection of various pathologies as well as it gives information about the location of the vessels and pathologies. The severity of the disease is directly related to the location of pathology near the macula. If the pathology or any symptom of DR is close to macula, the more severe is the disease[16].

Manual segmentation of the retinal fundus imaging is very long and tedious task. 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, ImageRet, Messidor, REVIEW (Retinal Vessel Image Set for Estimation of Widths), ROC Microaneurysm set[17], VICAVR database, CHASE database etc.

Section I contains the introduction of segmentation of retinal blood vessels 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 segmentation of retinal vessels and detection of various diseases 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 vessels and non-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] gave matched filter method for segmentation of blood vessels which achieved high sensitivity and specificity. Edward et al. proposed a multilayer perceptron neural network for automatically segment the blood vessels. 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. Staal et al.[3] used k-nearest neighbor classification method which achieves accuracy of 94.41%. Niemeiger et al. [4]used feature vector of 31 dimensions and KNN for classification and achieved accuracy of 94.16%. Bayesian classifier were used by Soares et al. [5]and achieve accuracy of 94.66%. 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%. SVM (Support Vector Machine) was used by Xu et al.[8] to classify the thin vessels in the image which is already segmented for the thick vessels.

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 DRIVE and STARE database. DRIVE database consists of 40 images divided into two sets named as testing and training sets both consists of 20 images each. The training as well as testing database has three and four pathological images. These images are of patients of diabetic retinopathy with the age group of 25-90 years. in both the sets, manually segmented images are present which will act as ground truth images. STARE database consists of 400 raw images Automated segmented images are compared with the ground truth images for the evaluation of performance parameters.

The proposed algorithm consists of following steps:-

Step 1:- Preprocessing of the RGB Image:- Since the original image contains noise, uneven illumination and other problems, so the first step of every segmentation algorithm is preprocessing. 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 preprocessing of RGB image includes:-

- **Extraction of Green Component from RGB Image:-** The RGB image has three components, Red, green and blue channel, but, the green channel contains the maximum information regarding to blood vessels. Figure 2 shows the RGB image and its corresponding channels.
- **Conversion into gray – scale and filtering of image:-** The green channel of the image is converted into gray scale for increasing its ability for segmentation. As the input image has uneven illumination and have noise, so some filtering is required for removal of noise. Noise is removed by using Gaussian filter. The image shown in Figure 3 is after conversion into gray scale and Gaussian filtering.
- **Contrast Enhancement:-**The image is further enhanced by using CLAHE (Contrast Limited Adaptive Histogram Equalization) method which increases the dynamic range of the image under consideration. Thus, contrast is enhanced, noise is removed and the image is suitable for further processing and segmentation of retinal vessels[9].

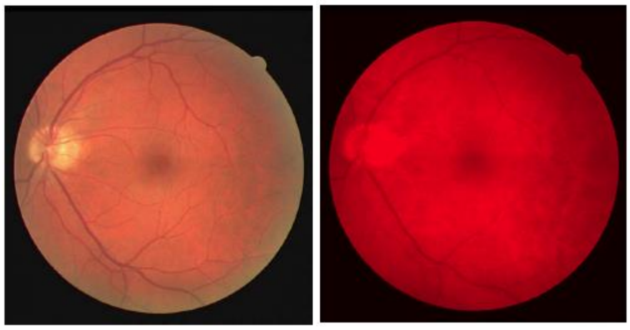
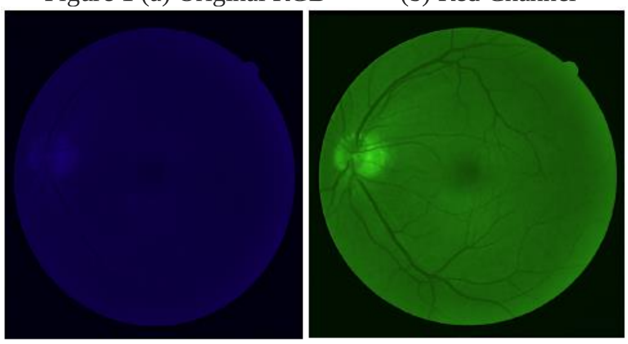


Figure 1 (a) Original RGB (b) Red Channel



(c) Blue Channel (d) Green Channel

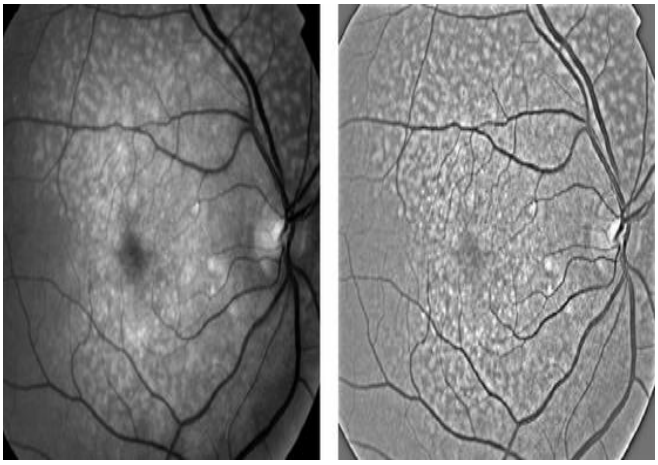


Fig 3: a) Image After Filtering b) Image after Enhancement of Contrast

Step 2:- Detection of Edges and Feature Extraction:- The edges of the retinal vessel images were detected using Canny edge operator. The Canny edge operator is the best among the other available operators such as Sobel. Prewitt, Robert, Laplacian of Gaussian (LoG). 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.

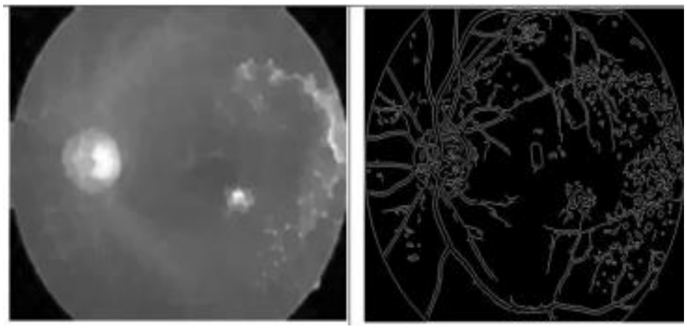


Fig 4: RGB Image and the result after application of Canny Operator

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.

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.

Step 4: 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 vessels and non-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.

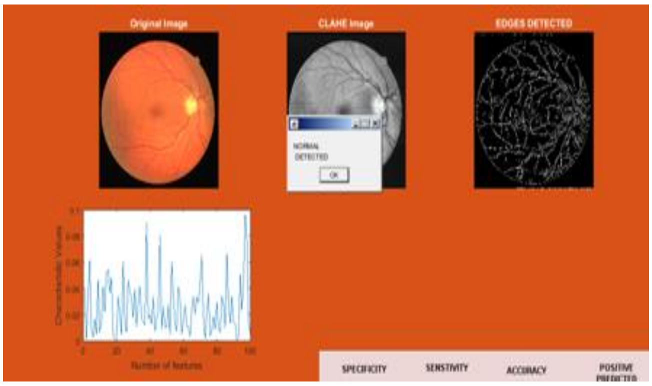


Fig 5: Normal image is detected as normal after classification process.

IV. RESULTS AND DISCUSSION

The various parameters used for the evaluation includes are Sensitivity, Specificity, Accuracy, Positive Predictive Rate, False Positive Rate. All these parameters can be calculated based on the values of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN)[17]. TP gives the value of number of pixels which are identified as true in both the manually segmented image and algorithm segmented image. TN gives the value of number of pixels which are identified as false in both the manually segmented and algorithm segmented image. FN gives the value of number of pixels which are identified as true in the manually segmented image but are non-vessel in algorithm identified image. FN gives the value of number of pixels which are identified as false in the manually segmented image but are vessel in algorithm identified image.

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

Table I: Performance parameters after Lion Optimization

Image No.	Sensitivity	Specificity	Accuracy	Positive Predictive Rate	False Positive Rate
1.jpg	94.34	96.88	95.54	98.64	97.44
2.jpg	88.22	98.64	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	89.10	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	90.10
10.jpg	92.10	98.98	97.44	93.12	92.12
AVERAGE	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. As these values are calculated by the computation of values of True Positive, True Negative, False Positive and False Negative which in turn is calculated by the comparison of automatically segmented images with the ground truth images.

Table 2 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 2: Comparison of Human Observer with Proposed System

Segmentation	**Sensitivity**	**Specificity**	**Accuracy**
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 (Contrast Limited Adaptive Histogram Equalization). This method gives knowledge about the location of the vessels which in helps in detection of severity of the disease. Features are extracted using Principal Component Analysis (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 detection of normal and abnormal images.

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