A New Era for the Blood Vessel Segmentation using NN approach and artificial bee colony optimization

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***Abstract*—**This Blood vessel segmentation of retinal images plays an important role in the diagnosis of eye diseases. Several pathologies affecting the retinal vascular structures due to diabetic retinopathy can be found in retinal images. Blood vessel segmentation from retinal images plays a crucial role for diagnosing complications due to hypertension, diabetes, arteriosclerosis, cardiovascular disease and stroke. Automatic and accurate blood vessel segmentation system could provide several useful features for diagnosis of various retinal diseases, and reduce the doctors' workload. However, the retinal images have low contrast, and large variability is presented in the image acquisition process, which deteriorates automatic blood vessel segmentation results. The research work in this paper presents a retinal vessel segmentation algorithm which uses a text on dictionary to classify vessel/non-vessel pixels. In the paper, the ABC optimization technique has been proposed for automatically retinal blood vessels segmentation. In contrast with ABC optimization algorithm, the existing genetic algorithm also has been implemented for the blood vessels segmentation. They proposed retinal blood vessels segmentation approach is tested on DRIVE database of retinal images. The results demonstrate that the performance of the proposed approach is comparable with state of the art techniques in terms of sensitivity, specificity, total time, Precision, Recall and accuracy. The proposed approach has been proven to be better as compared to the existing approach on the basis of the performance parameters.

Keywords*—Human eye; retinal vessel; blood vessel segmentation*

I. INTRODUCTION

Retina is the tissue lining the interior surface of the eye which contains the light-sensitive cells (photoreceptors). Photoreceptors convert light into neural signals that are carried to the brain through the optic nerves. In order to record the condition of the retina, an image of the retina (fundus image) can be obtained. A fundus camera system (retinal microscope) is usually used for capturing retinal images. Retinal im-age contains essential diagnostic information which assists in determining whether the retina is healthy or unhealthy. Retinal images have been widely used for diagnosing vascular and non-vascular pathology in medical society [1]. Retinal images provide information on the changes in retinal vascular structure, which are common in diseases such as diabetes, occlusion, glaucoma, hypertension, cardiovascular disease and stroke [2, 3]. These diseases usually change reflectivity, tortuosity, and patterns of blood vessels [4]. For example, hypertension changes the branching angle or tortuosity of vessels [5] and diabetic retinopathy can lead to neovascularization i.e., development of new blood vessels. If left untreated, these medical conditions can cause sight degradation or even blindness [6]. The early exposure of these changes is important for taking preventive measure and hence, the major vision loss can be prevented [7]. Automatic segmentation of retinal blood vessels from retinal images would be a powerful tool for medical diagnostics. For this purpose, the segmentation method used should be as accurate and reliable as possible. The main aim of segmentation is to differentiate an object of interest and the background from an image.

A. Structure of the human eye

Human eye is the light-sensitive organ that enables one to see the surrounding environment. It can be compared to a camera in a sense that the image is formed on the retina of eye while in a traditional camera the image is formed on a film. The cornea and the crystalline lens of the human eye are equivalent to the lens of a camera and the iris of the eye works like the diaphragm of a camera, which controls the amount of light reaching the retina by adjusting the size of pupil [13]. The light passing through cornea, pupil and the lens reaches the retina at the back of the eye, which contains the light sensitive photoreceptors. The image formed on the retina is trans-formed into electrical impulses and carried to the brain through the optic nerves, where the signals are processed and the sensation of vision is generated [32]. The general diagram of human eye is shown in Figure 1.

Figure

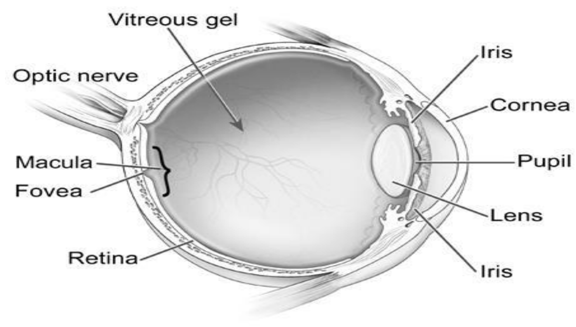

Fig.1 The structure of the human eye [16]

The small, yellowish central area of the retina which is around 5.5 mm in diameter is known as macula [14]. The macula and its center area (fovea) provide sharp central vision. A healthy macula can provide at least a normal (20/20) vision [35]. Fovea is densely populated with 'cone' photoreceptors which are responsible for the trichro-matic human color vision. Fovea contains no 'rod' photoreceptors which provide information on brightness. The L-, M- and S-cone cells are sensitive to long, middle, and short wavelength ranges in the visible part of the electromagnetic spectrum (i.e., 380-780 nm), respectively, whereas rod cells provide no color information [15]. Optic disc is the visible part of the optic nerve where the optic nerve fibers and blood vessels enter the eye. It does not contain any rod or cone photoreceptors, so it cannot respond to light. Thus, it is also called a blind spot. The retinal arteries and veins emerge from the optic disc. Retinal arteries are typically narrower than veins. Macula fovea, optic disc, veins and arteries are illustrated in Figure 2.

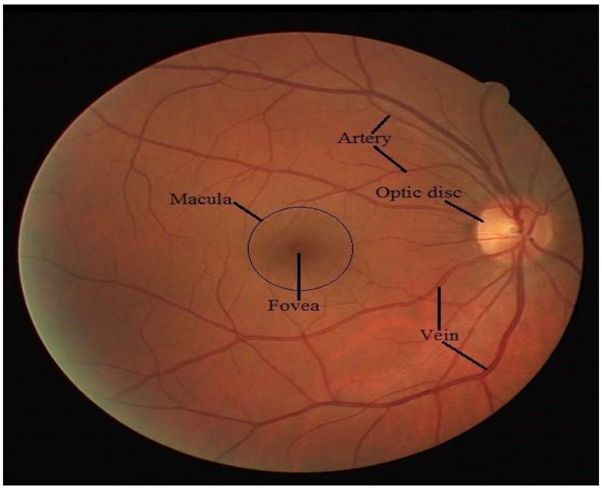

Fig. 2 Fundus image [11]

B. Retinal Blood Vessels

Segmentation of blood vessels is one of the essential medical computing tools for clinical assessment of vascular diseases. It is a process of partitioning an angiogram into non overlapping vascular and background regions. Based on the partitioning results, surfaces of vasculatures can be extracted, modeled, manipulated, measured and visualized. These are very useful and play important roles for the endovascular treatments of vascular diseases. Vascular diseases are one of the major sources of morbidity and mortality worldwide. Therefore, developing reliable and robust image segmentation methods for angiography has been a priority in research groups. The retinal blood vessel network provides nutrition to the eyes and removes waste from the retinal systems. While doing this, it must not interfere with the light transmission to the photoreceptors in the neural layer. Human eyes have evolved a two layer circulation systems to accommodate this need [1, 2]. The two circulation systems are uveal blood circulation and retinal blood circulation. The retina needs both systems to survive [3]. The uveal blood circulation supplies the outer layers of the eyes including the iris, ciliary body and the choroidal tissue and the retinal blood circulation supplies the inner portion of the eye as far as the neural layer. The two circulation systems do not connect to each other and complement each other to provide full blood support to the eyes. The nutrition and oxygen rich blood are delivered by highly elastic, thick walled arteries to the retina. Arteries and veins extend to smaller arterioles and venules, respectively and are connected with the capillary bed [4]. After nutrition and waste exchange in the capillary bed, the blood is returned by highly expandable, thin walled veins to the heart. The arterioles, capillaries and venules are collectively called the microcirculation of the retina.

C. Retinal Blood segmentation

The retinal vasculature is composed of arteries and veins appearing as elongated features, with their tributaries visible within the retinal image. There is a wide range of vessel widths ranging from one pixel to twenty pixels, depending on both the width of the vessel and the image resolution. Other structures appearing in ocular fundus images include the retina boundary, the optic disc, and pathologies in the form of cotton wool spots, bright and dark lesions and exudates as shown in Fig. 1.1 (b–d). The vessel [7] cross-sectional intensity profiles approximate a Gaussian shape. The orientation and grey level of a vessel does not change abruptly; they are locally linear and gradually change in intensity along their lengths. The vessels can be expected to be connected and, in the retina, form a treelike structure. However, the shape, size and local grey level of blood vessels can vary hugely and some background features may have similar attributes to vessels as illustrated in Fig. 1.1(a and d). Vessel crossing and branching can further complicate the profile model. As with the processing of most medical images, signal noise, drift in image intensity and lack of image contrast pose significant challenges to the extraction of blood vessels. Retinal vessels also show an evidence of a strong reflection along their centre line known as a central vessel reflex as evident in Fig. 1.1(a), which is more apparent in arteries than veins, is stronger at images taken at longer wavelengths, and typically found in the retinal images of younger patients.

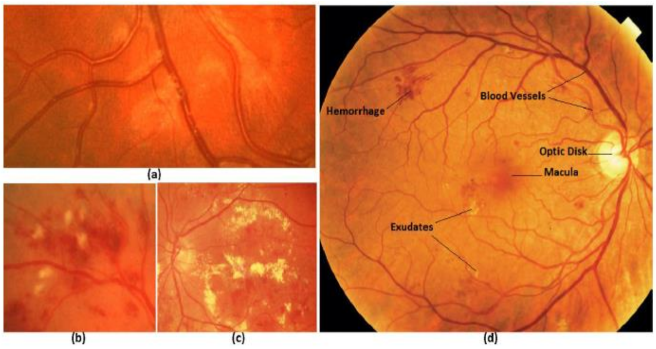

Fig.3 Morphology of retinal images: (a) central vessel reflex and uneven background, (b) cotton wool spots, (c) hard exudates, (d) anatomical structures in the retina's

II. RELATED WORK

Retinal blood vessel segmentation is achieved through assigning each pixel as either a vessel pixel or non-vessel pixel. The retinal vessel segmentation methodologies can be seen in different dimensions. In a broad sense, the vessel segmentation methodologies can be divided into two categories namely rule based techniques and pattern recognition based techniques.

Hassanien et al.[1] in 2015 proposed approach that makes use of the artificial bee colony optimization in conjunction with fuzzy cluster compactness fitness function with partial belongness in the first level to find coarse vessels. The dependency on the vessel reflectance is problematic as the confusion with background and vessel distortions especially for thin vessels, so there is a use of a second level of optimization. In the second level of optimization, pattern search is further used to enhance the segmentation results using shape description as a complementary feature. Thinness ratio was used as a fitness function for the pattern search optimization. The pattern search was a powerful tool for local search while artificial bee colony is a global search with high convergence speed. The proposed retinal blood vessels segmentation approach was tested on two publicly available databases DRIVE and STARE of retinal images. The results demonstrate that the performance of the proposed approach was comparable with state of the art techniques in terms of sensitivity, specificity and accuracy.

Lei Zhang et al.[2] in 2015 presented a retinal vessel segmentation algorithm which uses a texton dictionary to classify vessel/non-vessel pixels. However, in contrast to previous work where filter parameters are learnt from manually labeled image pixels our filter parameters are derived from a smaller set of image features that were called key points. A Gabor filter bank, parameterized empirically by ROC analysis, was used to extract key points representing significant scale specific vessel features using an approach inspired by the SIFT algorithm. They determined key points using a validation set and then derive seeds from these points to initialize a k-means clustering algorithm which builds a texton dictionary from another training set. During testing they used a simple 1-NN classifier to identify vessel/non-vessel pixels and evaluate the system using the DRIVE database. They achieved average values of sensitivity, specificity and accuracy of78.12%, 96.68% and 95.05%, respectively. They found that clusters of filter responses from key points were more robust than those derived from hand-labeled pixels. This in turn yields textons more representatives of vessel/non-vessel classes and mitigates problems arising due to intra and inter-observer variability.

Hassan et al. [3] in 2015 presented a blood vessel segmentation approach, which can be used in computer based retinal image analysis to extract the retinal image vessels. Mathematical morphology and K-means clustering were used to segment the vessels. To enhance the blood vessels and suppress the background information, they performed smoothing operation on the retinal image using mathematical morphology. Then the enhanced image was segmented using K-means clustering algorithm. The proposed approach was tested on the DRIVE dataset and is compared with alternative approaches. Experimental results obtained by the proposed approach showed that it was effective as it achieved average accuracy of 95.10% and best accuracy of 96.25%.

Biradar et al.[4] in 2015 discussed the blood vessel identification that was performed on the basis of blood vessel characteristics such as blood vessel's orientation, cross-sectional area, surface shapes, and abnormal regions volumes. The quantitative analysis of retinal images is of increasing importance in the diagnosis of the blood vessel abnormalities. An automated method for identification of optic disc has two methodologies named as location methodology and boundary segmentation methodology.

Zhang et al.[5] in 2015 proposed an automatic unsupervised blood vessel segmentation method for retinal images. Firstly, a multidimensional feature vector was constructed with the green channel intensity and the vessel enhanced intensity feature by the morphological operation. Secondly, self organizing map (SOM) is exploited for pixel clustering, which is an unsupervised neural network. Finally, each neuron in the output layer of SOM is classified as retinal neuron or non-vessel neuron with Otsu's method, and the final segmentation result were found. The proposed method was validated on the publicly available DRIVE database, and compared with the state-of-the-art algorithms.

Soumia and Nadjia in 2015[6] proposed a new technique of entropic thresholding based on Gray Level Spatial Correlation (GLSC) histogram which took into account the image local property. Results obtained show robustness and high accuracy detection of retinal vessel tree.

Yan et al. in 2015[7] proposed an automated method to segment the blood vessels in retinal images using the hessian-based filter and random walk algorithms. The aim of the hessian-based vascular filtering was to enhance the vessel structures. Local thresholding was also used to obtain seed groups for the random walk segmentation. Experiments on the DRIVE (Digital Retinal Images for Vessel Extraction) database showed that the proposed method achieved better performance.

Bhatia et al. in 2015[8] proposed an efficient supervised algorithm for automatic blood vessel segmentation. The proposed method was based on common image enhancing techniques and basic morphological operations. The proposed method outperformed other existing vessel segmentation methods and also outperformed non-expert human segmentation. Also, the running time of the proposed method was better than other state-of-the-art methods. It can extract the vessel network of one image in just about 13 seconds (approx.).

Wu et al. [17] in 2011 use adaptive contrast enhancement that is based on the standard deviation of a Gabor Filter Response (GFR) image window to highlight vessels. Two randomly selected images from the STARE data set are used for parameter training. A tracking segmentation method is tested on the remaining 18 images. An accuracy of 75% is reported on the small vessels which consistute 42% of the total vessel pixel count.

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III. PROBLEM FORMULATION

Retinal vessel segmentation and delineation of morphological attributes of retinal blood vessels, such as length, width, tortuosity or branching pattern are utilized for diagnosis of various cardiovascular and ophthalmologic diseases such as diabetes, hypertension, arteriosclerosis and chorodial neovascularization .Manual segmentation of retinal blood vessels is a long and tedious task which also requires training and skill. It is commonly accepted by the medical community that automatic quantification of retinal vessels is the first step in the development of a computer-assisted diagnostic system for ophthalmic disorders. There is a strong need of the automatic blood vessel segmentation technique that can achieve higher accuracies which will help in detection of various eye diseases An automated retinal blood vessels segmentation approach based on two levels optimization principles. They proposed approach makes use of the artificial bee colony optimization in conjunction with fuzzy cluster compactness fitness function with partial belongings in the first level to find coarse vessels. The dependency on the vessel reflectance is problematic as the confusion with background and vessel distortions especially for thin vessels, so we made use of a second level of optimization. In the second level of optimization, pattern search is further used to enhance the segmentation results using shape description as a complementary feature. Thinness ratio is used as a fitness function for the pattern search optimization. Then after apply the proposed artificial bee colony optimization to segments the retinal blood vessels. And then use the Edge detection technique to detect the shape of retinal blood vessels segmented image. They proposed retinal blood vessels segmentation approach is tested on DRIVE database of retinal images. The results demonstrate that the performance of the proposed approach is comparable with state of the art techniques in terms of sensitivity, specificity, total time, Precision, Recall and accuracy.

A. Reseach Objectives

The research work presents a technique for automatically segmenting retinal blood vessels from the fundus image for retinal analysis and disease diagnosis. The research work comprises of three phases viz., image pre-processing, supervised and unsupervised learning and image post-processing. The objective of the research includes:

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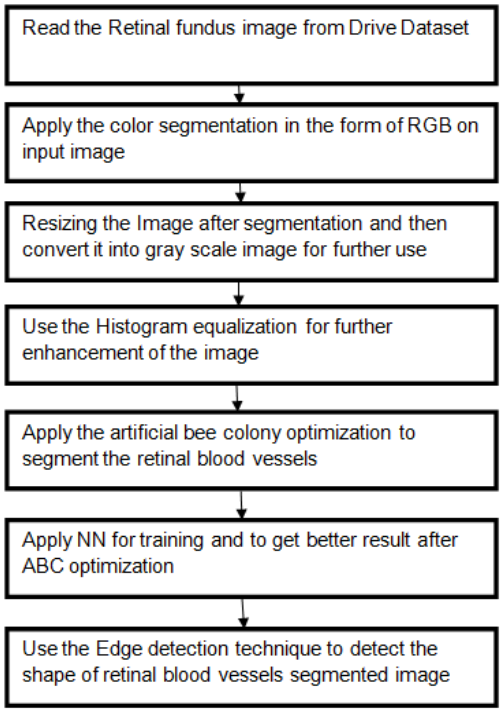
1. To study and understand the existing blood vessels segmentation techniques.
2. To propose and implement Artificial Bee Colony optimized method using Neural Networks to segment the blood vessels.
3. To compare it with existing technique and the proposed technique using the parameters given by sensitivity, specificity, Total Time, Precision, Recall and Accuracy.

B. Research Methodology

Input: - Input the required fundus image from the Drive dataset collection for preprocessing

Output: - To receive final vessel segmented image



IV. RESULTS & DISCUSSION

The implemented applications were tested using retinal images from publically available databases: DRIVE; and the results were compared against the corresponding ground truth images to calculate the performance measures of the proposed algorithms with existing algorithm. Retinal vessel segmentation algorithms are a fundamental component of automatic retinal disease screening systems. This work examines the blood vessel segmentation methodologies in two dimensional retinal images acquired from a fundus camera and a survey of techniques is presented. The aim of the research work is to review, analyze and categorize the retinal vessel extraction algorithms, techniques and methodologies, giving a brief description, highlighting the key points and the performance measures. We intend to give the framework for the existing research; to introduce the range of retinal vessel segmentation algorithms; to discuss the current trends and future directions and summarize the open problems. The performance of algorithms is compared and analyzed on publicly available databases (DRIVE) of retinal images using a number of measures which include accuracy, true positive rate, false positive rate, sensitivity, specificity and area under receiver operating characteristic (ROC) curve. The segmentation of blood vessels is useful for the diagnosis of diseases or in the assessment of the efficacy of therapy. Diameter and branching angles of retinal blood vessels are important criteria in these tasks, [1, 2]. These measurements can be computed by segmenting retinal blood vessels. There have been many studies on the segmentation of blood vessels but only few of them focus on retinal blood vessels in particular. We can classify the retinal segmentation method into two categories: supervised methods which require manually labeled images [4] and unsupervised methods [5, 6].

A. Steps to implement the research work

The research work presents a technique for automatically segmenting

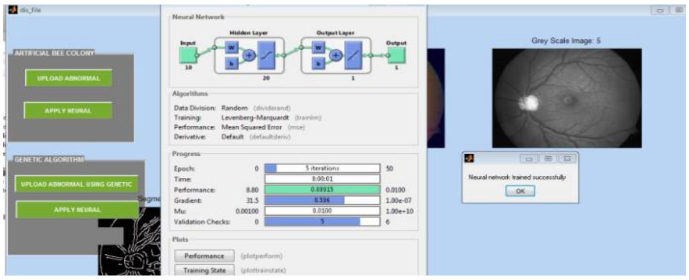


Fig.4 First screen of the output window

Above figure shows the first screen of the window, where we have the option to run the proposed ABC optimization algorithm and Genetic algorithm.

CASE 1: Output Screens of Existing Genetic algorithm for both normal and abnormal images of the drive database

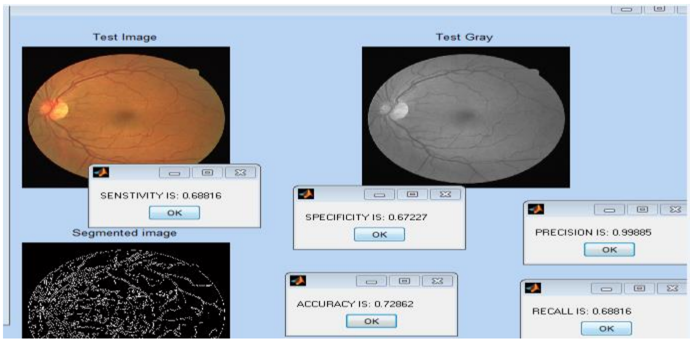


Fig. 5 output of the vessels using Genetic

Output consists of Preprocessing of images, color channel extraction and contrast enhancement. After getting preprocessed image for the formation of feature vector, we will apply the neural network for vessels and non-vessels for the formation of segments for blood vessels segmentation.

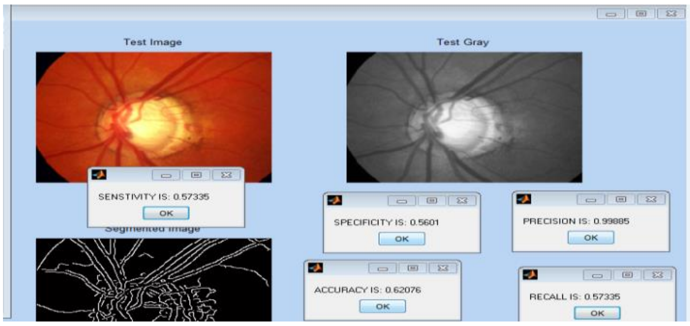


Fig.6 output of the non-vessels using Genetic

Case 2: Output Screens of Proposed ABC algorithm for both normal and abnormal images of the drive database

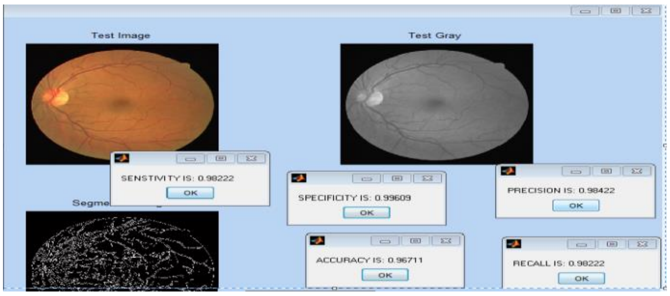


Fig. 7 output of the vessels detection using Proposed ABC Optimization

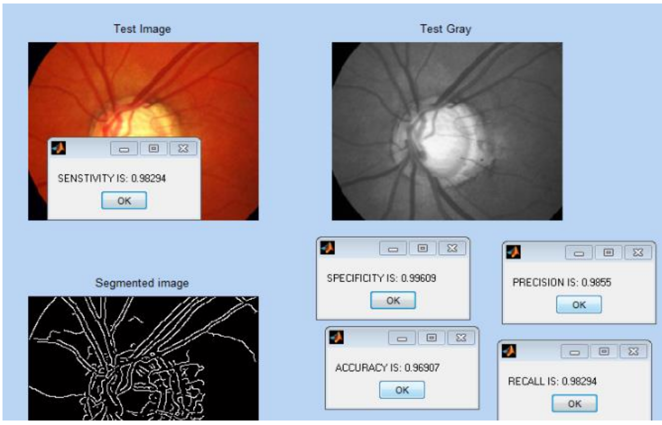


Fig.8 non-vessels detection using proposed ABC optimization

Above figures, clearly shows that the different operations performed on the fundus image for blood vessels segmentation. Finally, we come to conclude the results in terms of different parameters such as accuracy, sensitivity and specificity under Receiver operating characteristic (ROC) curve for true positive rate and false positive rate. Similarly we can apply the same operation on different fundus images from Drive dataset for the Blood vessel segmentation.

B. *Output Table*

TABLE I. Abnormal Images Using ABC Testing

S.no	Image name	Sensitivity	Specificity	Accuracy	Precision	Recall
1	UPAB1	0.98294	0.99609	0.96907	0.98550	0.98294
2	UPAB2	0.99224	0.98409	0.96719	0.98428	0.98224
3	UPAB3	0.99296	0.98509	0.96913	0.98554	0.98296
4	UPAB4	0.98218	0.99491	0.9671	0.9845	0.98218
5	UPAB5	0.98202	0.99332	0.96657	0.98387	0.98202

TABLE II. Abnormal Images Using Genetic Testing

S.no	Image name	Sensitivity	Specificity	Accuracy	Precision	Recall
1	UPAB1GT'	0.57335	0.5601	0.62076	0.99885	0.57335
2	UPAB2GT	0.57361	0.56036	0.62101	0.99885	0.57361
3	UPAB3GT	0.57286	0.55961	0.62029	0.99884	0.57286
4	UPAB4GT	0.57372	0.56047	0.62112	0.99885	0.57372
5	UPAB5GT	0.57325	0.56	0.62067	0.99885	0.57325

TABLE III. Normal Images Using ABC Testing

S.no	Image name	Sensitivity	Specificity	Accuracy	Precision	Recall
1	UPN1	0.98222	0.99609	0.96711	0.98422	0.98222
2	UPN2	0.98303	0.99514	0.96932	0.98566	0.98303
3	UPN3	0.98198	0.99619	0.96646	0.9838	0.98198
4	UPN4	0.98216	0.99709	0.96696	0.98413	0.98216
5	UPN5	0.982	0.99509	0.96652	0.98384	0.982

TABLE IV. Normal Image Using Genetic Testing

s.no	Image name	Sensitivity	Specificity	Accuracy	Precision	Recall
1	UPN1GT	0.68816	0.67227	0.72862	0.99885	0.68816
2	UPN2GT	0.68816	0.67227	0.72862	0.99885	0.68816
3	UPN3GT	0.68818	0.67228	0.72864	0.99885	0.68818
4	UPN4GT	0.68825	0.67235	0.7287	0.99885	0.68825
5	UPN5GT	0.68807	0.67217	0.72853	0.99885	0.68807

C. Graphical Interfaces

The graphical analysis shows that the result of different performance parameters for the Blood vessel segmentation. The graphs elaborate the performance of the proposed techniques by computing the values of precision, sensitivity, specificity, and thresholding for different drive dataset images.

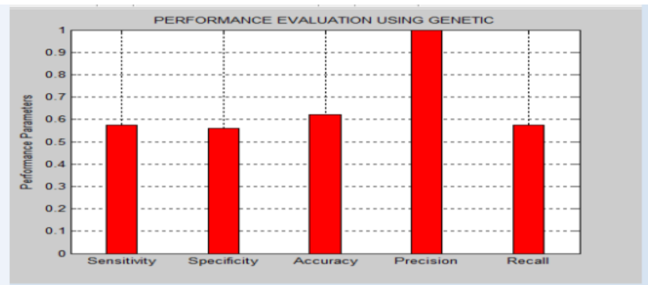


Fig.8 Performance evaluation using Genetic Algorithm

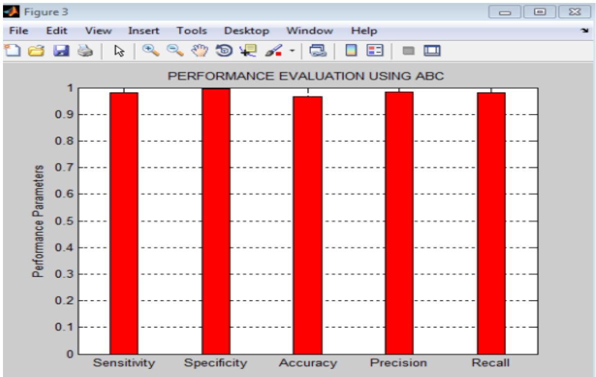


Fig.9 Performance evaluation using ABC Algorithm

Above figure clearly shows that the average performance of the Accuracy, precision, sensitivity, specificity and Recall of proposed method is much higher than the existing technique as per computed from different images of Drive dataset.

V. CONCLUSION

One of the most important diseases that cause retinal blood vessels structure to change is diabetic retinopathy that leads to blindness. Diabetic affects almost 31.7 million Indian populations, and has associated complications such as stroke, vision loss and heart failure. Diabetic disease is occurs when the pancreas does not secrete enough amount of insulin. This disease affects slowly the circulatory system including that of the eye. Diabetic retinopathy is a common cause of vision loss among the diabetic population. Despite various advances in diabetes care over the years, vision loss is still a potentially devastating complication in diabetic population. Blood vessel is one of the most important features in retina for detecting retinal vein occlusion, grading the tortuosity for hypertension and early diagnosis of glaucoma. The segmentation of blood vessels is an important preprocessing step for the early detection of retinal diseases. Because of multifarious nature of the vascular network, the manual vessel segmentation is very difficult and time consuming, so the researchers have proposed several automated methods for retinal vessel segmentation which are grouped as supervised and unsupervised based on the vessel classification techniques. Accurate segmentation of retinal blood vessels is an important task in computer aided diagnosis and surgery planning of retinopathy. Despite the high resolution of photographs in fundus photography, the contrast between the blood vessels and retinal background tends to be poor. Furthermore, pathological changes of the retinal vessel tree can be observed in a variety of diseases such as diabetes and glaucoma. Vessels with small diameters are much liable to effects of diseases and imaging problems. Vessel segmentation approach uses supervised and unsupervised method to segment the blood vessel features. The unsupervised method sub divided into techniques based on the morphological processing, matched filter, multi scale analysis and vessel tracking.

The research work is performed to implement the image preprocessing steps such as cropping, color space transformations, channel extraction, color enhancement, gabor filter. After that, preprocessed images have been used to form feature vector and then optimized the selected features by using proposed ABC optimization techniques And the performance is measured using the different parameters by computing the averaging of parameters values. The proposed retinal blood vessels approach is tested on publicly available database DRIVE of retinal images. The training part is done by using the neural network. The results demonstrate that the performance of the proposed approach is comparable with state of the art techniques in terms of accuracy, sensitivity, specificity and thresholding.

VI. FUTURE WORK

The retinal vessel segmentation technique gives the knowledge about the location of vessels which paves a way for the screening of diabetic retinopathy. The main advantage of the proposed method is the ability to identify and classify the image pixels as vessels or non-vessels, automatically. The future direction of segmentation research will be towards developing faster, more accurate, and more automated techniques Accuracy of the segmentation technique is a crucial criteria due to the nature of the work. In future, performance of these segmentation based algorithms can be improved based on performance evaluation parameters. Although the performance of the proposed method (sensitivity, specificity, and accuracy) is good in Drive dataset, we will also use other datasets for the Blood vessel segmentation in future. Along with that, other optimizations techniques can also be explored for feature optimization to improve the accuracy.

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