Integrated Gabor Filter and Trilateral Filter for Exudate Extraction in Fundus Images

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Abstract—Image segmentation is the process of dividing an electronic digital image into numerous sub-images. Its objective is to categorize image into various regions in such a way that every potential object in image gets individual sector. Instinctive recognition of diabetic retinopathy wounds, like exudates can provide opportunity to identify certain diseases. Lack of accuracy in these techniques can lead to fatal results because of incorrect treatment. So, there is a great need for automation techniques with high accuracy for retinal disease identification. Several automation techniques have been proposed for retinal image analysis which can detect the exudates in fundus images in more promising manner. The related work has found that the issue of noise in fundus images is ignored in the majority of existing literature. Although Gabor filter bank has shown significant results over available techniques, but it is poor in its speed. Also it is not very efficient for multiple kinds of noises at a same time. Therefore to improve the accuracy of exudate extraction further a Hybrid Gabor filter bank with trilateral based filtering technique is proposed. This filtering will use improved trilateral filtering which enables us to detect exudates even in highly corrupted noisy images.

Index Terms—Image segmentation, Exudates segmentation, Hybrid Gabor filter, Fundus images

I. INTRODUCTION

Digital Image Processing is a method which deals with manipulation of a digital image with the help of a digital computer. DIP deals with the computer-based processing of digital images.

Image segmentation is the method of extracting required components from an image. Segmentation attempts to find an object of interest in the image. It includes dividing the image into 2 kinds of regions - either object or background to extract the desired information. Segmentation takes place naturally in the human visual system. Humans are specialists in identifying patterns and shapes and making decisions primarily depending on the visual characteristics.

A. Medical Image Segmentation

Segmentation is very important in computer-based diagnosing of medical images. The target of image segmentation is to divide a picture in non-overlapping components on the basis of intensity and texture of the image. In segmentation technique, the primary step is de-noising or image smoothing, to remove noise from the image like salt and pepper noise. Then, Thresholding is done, in which objects are extracted from the background based on the threshold values. This technique is helpful in segmenting images having light objects against a dark background or vice versa. Clustering technique is employed for identification of affected area in any medical image.
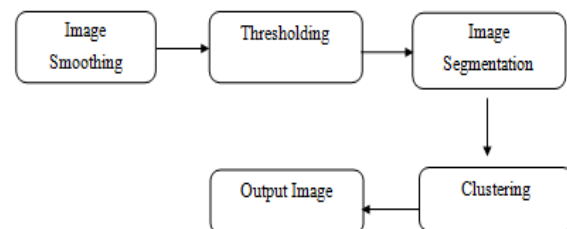

Fig.1. Basic steps of medical image segmentation

B. Retinal Vessel Segmentation

Basically, Retina is a layer of tissue at the inner surface of the eye which converts incoming light to the neural signal which is further processed by the brain. The appearance of the retina is a key indication of a wide range of eye diseases amongst individuals and could be diagnostic tool of a variety of problems concerning health and wellbeing of individuals. Many morphological properties of retinal arteries and veins (e.g. diameter, length, and branching angle) are of diagnostic significance and so are used in detecting and monitoring the disease progression, treating and evaluating some cardiovascular and ophthalmologic diseases.

Characteristics of retinal images like the displacement of arteries and vessels in the OD (optic disk) are useful in automatic detection of various problems related to eye.

In this paper, an Integrated Gabor filter with trilateral based filtering is proposed for exudate extraction in fundus images. Section II describes various vessel segmentation techniques. The related work is discussed in Section III. Gaps in literature and proposed methodology are discussed in Section IV and V respectively. The performance analysis and results of the proposed technique are described in Section VI. Section VII discusses Conclusions.

II. VESSEL SEGMENTTION TECHNIQUES

Retinal vessel segmentation techniques describe various approaches to extract and analyze blood vessels from the fundus images. Numerous techniques for segmenting retinal vessels have been proposed over the time. Various techniques of vessel segmentation are-

A. Multiscale Feature Extraction and Region Growing

In this technique, parallelism is applied to the images by dividing an image into constituent sub images and every sub image can be processed simultaneously with other images within the available memory per processor to speed up the segmentation process. Region growing segmentation techniques work by starting from a seed point and combining the pixels depending on some prefixed criterion like similar intensity values and the pixels which lie spatially closer to the growing pixel. It is considered that the pixels having similar intensity values and nearby one another belong to the same object.

B. Hybrid Filtering

Hybrid filtering technique for segmenting retinal vessels is generally a pre-processing step in various areas to extract the vessels from the retinal images. In this technique, a Hessian matrix is used and filter is used. Orientation of the retinal vessels is provided by eigen vectors of the Hessian matrix and the edge constraints can be used to suppress the response of spurious boundary edges.

C. Gabor Filter

Dennis Gabor proposed the Gabor filtering technique which was later on used by Daugman. Gabor filter is a linear filtering technique which is widely used for edge detection. Gabor filters have an advantage of having frequency and orientation representations identical to the human visual system, and so it is very helpful in segmenting retinal vessel structures. Gabor filters are basically bandpass filters and are mainly used in feature extraction and texture analysis for processing images.

This filtering technique makes use of multi-scale Gabor filter characterized by one free parameter that determines the scale to identify the pixels called keypoints using the scale invariant feature transform (SIFT). Filter-response vectors derived from keypoints are used to initialize a clustering algorithm which generates textons which are eventually used for the classification of vessel pixels or non-vessel pixels in the input images. Then a process called model selection is used to identify keypoints from a small training set (N = 10) of retinal images. Then using these keypoints, a texton dictionary is built. In this second training stage, a k-NN clustering algorithm is initialized with seeds found by matching keypoints identified by the model selection stage to those in the training set.

Leung and Malik characterize textons by its response to a filter bank $(F_1, F_2, \ldots, F_n)$.

$$R = F_1 \times I(x, y), F_2 \times I(x, y), \ldots, F_n \times (x, y)$$

If the filter bank convolved with an input image I(x,y) the response at each pixel will depend on specific local structures and on the design of the filter bank.

III. RELATED WORK

This section describes the study of the related work done in the existing literature corresponding to retinal vessel segmentation.

Zhang et al. [2015] [6] presented an algorithm for segmenting retinal vessel structures which makes use of a texton dictionary to categorize vessel pixels or non-vessel pixels. This algorithm also uses Key points which are a small set of image features to derive the parameters for filtering. A Gabor filter bank presented in this paper has main aim of extracting key points from an image which represent significant information regarding vessel features with the help of SIFT algorithm.

Bhuiyan et al. [2013] [7] have discussed that the Age-related macular degeneration (AMD) is the main reasons for vision defect among the aged people and identification of persons with first stages of AMD is vital while considering the preventative strategies for late AMD. They proposed a technique for drusen detection from standard color retinal images which enables quick, accurate and automated method to determine characteristics of drusen. The methodology achieved 100% accuracy to detect drusen region.

Kamboj et al. [2013] [8] explained that enhancing a corrupted image by removing noise is an important step in digital image processing for better perception. Various filters are used for removing various types of the noise from the images. A Filter can be classified as linear filter (whose outcome is a linear function of its input) and non-linear filter (whose outcome is a non-linear function of its input).

Esakkirajan et al. [2011] [9] presented a filter named Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF). This technique is superior to existing algorithms for removing noise. The MDBUTMF algorithm gives is more efficient in comparison to existing techniques even in the presence of very high noise.

Giachetti et al. [2011] [10] gave a method to the segment the optic disk (OD) from the binary

fundus images using morphological segmentation to decouple the vessel and background information. After this, a multi resolution optimization scheme is applied to the image to find elliptic contours.

Joshi et al. [2011] [11] presented an OD segmentation technique which combines the local information of images around every point of interest with the help of a multi-stage strategy.

Marin et al. [2011] [12] gave a methodology to isolate the blood vessels in the retinal images on the basis of a neural network (NN) scheme to classify pixels. In this technique, a 7-D vector composed of gray-level and moment invariants-based features is computed.

Santos et al. [2011] [13] proposed an efficient image processing method to segment drusen in the digital fundus images. The proposed algorithm aims at detecting AMD progression from a group of longitudinal images.

Fang et al. [2010] [14] gave a powerful technique to automatically segment hard exudates from the retinal image. This technique uses a course-to-fine strategy, in which initially a coarse value is obtained in which some negative samples are allowed, then these negative samples are get rid of step by step. To obtain a coarse segmentation result, they also gave a multi-scale background subtraction technique. HEs are extracted by a SVM classifier by excluding the optic disc region from the coarse value. The important points described in the paper are: (A) An efficient technique for segmentation of HE's (Hard Exudates); (B) A segmentation technique to mix multi-channel information; (C) Using the filter for segmenting the OD.

Gonzalez et al. [2010] [15] described a methodology for human retinal vessel segmentation with the help of graph cut methodology. In this method, firstly a graph is made by rough segmentation from a pre-processed image. The proposed technique was evaluated on two datasets and then compared with other techniques and it was concluded that this technique yields better performance than other unsupervised methods.

Hooshyar et al. [2010] [16] described a fuzzy clustering technique on the basis of Ant Colony Algorithm. Analysis of eigen values of Hessian matrix and Gabor filter bank are used to extract features of color retinal images. Artificial ants in the image make use of these features for finding and clustering processes. Lupascu et al. [2010] [17] presented a technique for vessel segmentation in which for every pixel in the image, a 41-D feature vector is made, which encodes the information on the local intensity structure, spatial properties, and geometry at multiple scales.

Welfer et al. [2010] [18] gave a technique to segment the OD (optic disk) in fundus images with the help of mathematical techniques. The experimental results are dependent upon two eye databases and prove that this technique can achieve a better performance in comparison to other algorithms.

Nayak et al. [2009] [19] has discussed that the Glaucoma is an illness of the optic nerve which primarily affects the optical disc (OD) because of enlargement of the cup size of the eye. Digital image process techniques,

lik.e preprocessing, thresholding and morphological operations, are extensively used for the automated identification of optical disk and blood vessels.

Kong et al. [2008] [20] gave a color image segmentation scheme that combines the hue-preservation color image equalization and segmentation techniques. The experimental results showed that the hemorrhagic spots and the important blood vessels are properly segmented as compared to the earlier technique.

IV. GAPS IN LITERATURE

This section describes various issues in the existing technique. The literature survey has found that the majority of existing exudate segmentation techniques suffers from the following issues-

1. The issue of noise in fund us images is ignored in the majority of existing literature.
2. Although Gabor filter bank has shown significant results over available techniques, but it is poor in its speed.
3. The Gabor filter bank is rich in preserving the edges but not so efficient for high density of multiple noises.

V. METHODOLOGY

This section describes the sequence of steps followed in the proposed technique. Fig.2 is the flowchart showing steps for segmenting the retinal vessels from a human fundus image using the proposed methodology.
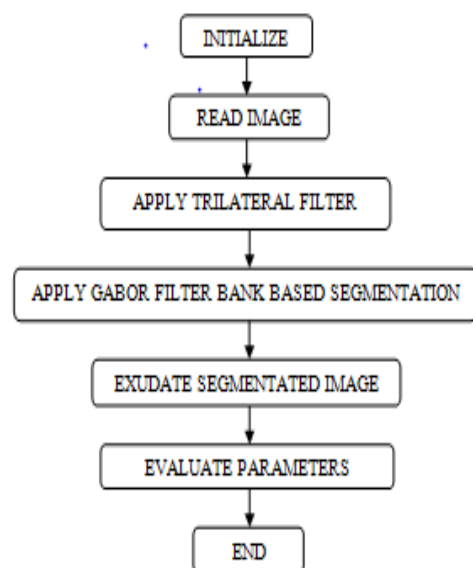

Fig.2. Flowchart of the proposed technique

The main steps of proposed technique are-

1. Input images in MATLAB.

- Read the input retinal image.
- Read mask of the image
- Read the ground truth of an image.

2. Add salt and pepper noise to the image.
3. Apply trilateral filter to image for noise reduction.
4. Gray scaling of an image.
5. Apply Gabor filter bank based segmentation on gray scale image.

- Gabor filter bank is used at multiple scales to extract the features from the image.
- Then points of interest also known as key points are extracted from the retinal image.
- Textons are generated from the image. These textons are the small lines and blobs that are present in an image.

6. Retinal vessel Segmented image is obtained.
7. Evaluate parameters to compare existing and proposed techniques.

VI. Performance Analysis and Results

This section contains the cross validation considering existing and proposed techniques. The proposed algorithm using Hybrid Trilateral Gabor Filter Bank was applied on 10 images and their output was measured in terms of five parameters i.e. SN (Sensitivity), SP (Specificity), ACC (Accuracy), PPV (Positive and Negative predictive value), FDR (False Detection Rate).

In this section these parameters and their results are described by comparing these parameters w.r.t existing and proposed methodologies.

1) SENSTIVITY (SN)

Sensitivity is a statistical measure of the performance defining the quality or condition of being sensitive. Sensitivity can also be referred as true positive rate. It is the proportion of positives which can be identified accurately. Higher the value of sensitivity, better results can be obtained. It can be calculated as-

$$SN = TP/(TP + FN) \qquad (1)$$

Table 1 shows the comparison of SN values for the existing and proposed algorithm. The value of proposed SN is higher as compared to existing SN for the 10 input images, thus it shows better result than the existing algorithm.

Table 1. The results of parameter SN for 10 input images.

Image Name	Existing SN	Proposed SN
Img1	0.8917	0.9974
Img2	0.9200	0.99707
Img3	0.9167	0.99922
Img4	0.8834	0.99995
Img5	0.9285	0.99979
Img6	0.9350	0.99952
Img7	0.8568	0.99976
Img8	0.9296	0.99754
Img9	0.8560	0.99991
Img10	0.8547	0.99984

Fig.3 shows the graph of comparison of SN values for the Existing and proposed algorithm. The blue color in graph represents the SN value calculated using Gabor filter bank, maroon color represents the SN value calculated using hybrid trilateral Gabor filter. Value of SN is higher thus shows that proposed algorithms shows better result.
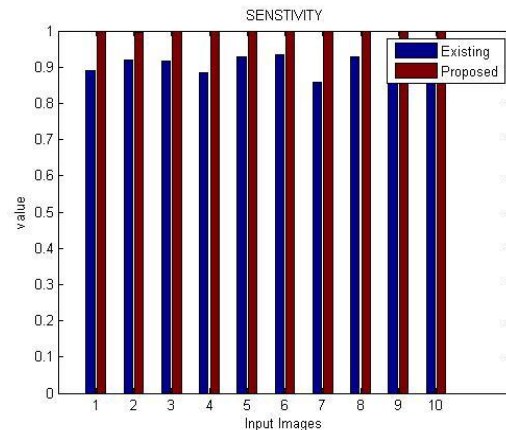

Fig.3. Comparative analysis of parameter SN for 10 input images

2) SPECIFICITY (SP)

Specificity is a statistical measure of the performance defining the quality or condition of being specific. Specificity can also be referred as true negative rate. It is used to measure the proportion of negatives which can be correctly identified. Higher the value of specificity, better results can be obtained. It can be calculated as-

$$SP = TN/(TN + FP) \qquad (2)$$

Table 2 shows the comparison of SP values for the existing and proposed algorithm. The value of proposed SP is higher as compared to existing SN for the 10 input images, thus it shows better result than the existing algorithm.

Table 2. The results of parameter SP for 10 input images

Image Name	Existing SP	Proposed SP
Img1	0.9846	0.99136
Img2	0.9642	0.97606
Img3	0.9806	0.98094
Img4	0.9807	0.9853
Img5	0.9169	0.9258
Img6	0.9895	0.98713
Img7	0.9873	0.99152
Img8	0.9900	0.99551
Img9	0.9870	0.99875
Img10	0.9790	0.9786

Fig.4 shows the graph of comparison of SP values for the existing and proposed algorithms. The blue color in graph represents the SP value calculated using Gabor filter bank, maroon color represents the SP value calculated using hybrid trilateral Gabor filter. Value of SP is higher thus shows that proposed algorithms shows better result.
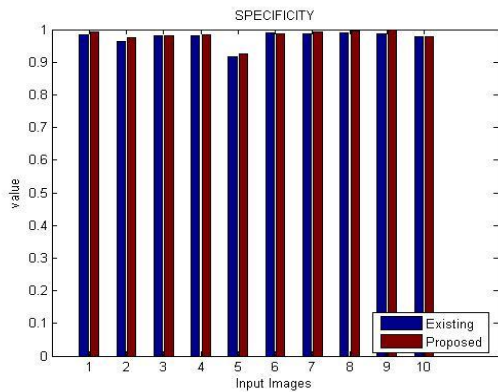

Fig.4. Comparative analysis of parameter SP for 10 input images

3) *ACCURACY (ACC)*

Accuracy is the amount of closeness of measurements of a quantity to that quantity's true value. Higher value of accuracy better will be the results. It can be calculated as-

$$ACC = TP + TN /(TP + FP + FN + TN) \qquad (3)$$

Table 3 shows the comparison of ACC values for the existing and proposed algorithm. The value of proposed ACC is higher as compared to existing ACC for the 10 input images, thus it shows better result than the existing algorithm.

Table 3. The results of parameter ACC for 10 input images

Image Name	Existing ACC	Proposed ACC
Img1	0.9771	0.99977
Img2	0.9795	0.9997
Img3	0.9766	0.99993
Img4	0.9789	0.99999
Img5	0.9820	0.99998
Img6	0.9852	0.99995
Img7	0.9782	0.99998
Img8	0.9859	0.99983
Img9	0.9768	0.99999
Img10	0.9788	0.99998

Fig.5 shows the graph of comparison of ACC values for the existing and proposed algorithms. The blue color in graph represents the ACC value calculated using Gabor filter bank, maroon color represents the ACC value calculated using hybrid trilateral Gabor filter. Value of ACC is higher thus shows that proposed algorithms shows better result.
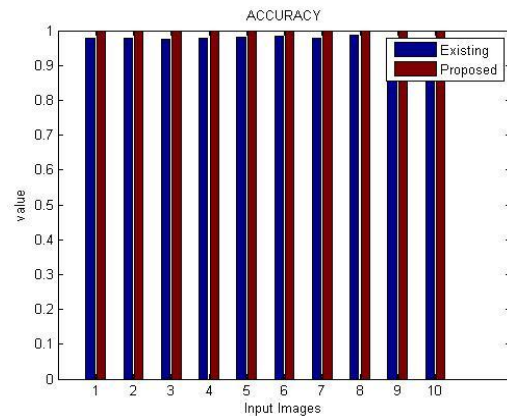

Fig.5. Comparative analysis of parameter SP for 10 input images

4) *POSITIVE AND NEGATIVE PREDICTIVE VALUE (PPV)*

The PPV is defined as-

$$PPV = TP /(TP + FP) \qquad (4)$$

Where TP is the event when the test makes a positive prediction, and the subject has a positive result. The FP is the event when the test makes a positive prediction and the subject has a negative result.

Table 4 shows the comparison of PPV values for the existing and proposed algorithm. The value of proposed PPV is higher as compared to existing PPV for the 10 input images, thus it shows better result than the existing algorithm.

Table 4. The results parameter PPV for 10 input images.

Image Name	Existing PPV	Proposed PPV
Img1	0.8341	0.98319
Img2	0.8221	0.92277
Img3	0.7587	0.92732
Img4	0.8517	0.93251
Img5	0.8676	0.91704
Img6	0.8847	0.9016
Img7	0.8357	0.99504
Img8	0.8733	0.95597
Img9	0.8465	0.90771
Img10	0.8636	0.97322

Fig.6 shows the graph of comparison of PPV values for the existing and proposed algorithms. In this graph, the SP values of existing images are compared with the values of proposed images. The blue color in graph represents the PPV value calculated using Gabor filter bank, maroon color represents the PPV value calculated using hybrid trilateral Gabor filter. Value of PPV is higher thus shows that proposed algorithms shows better result.
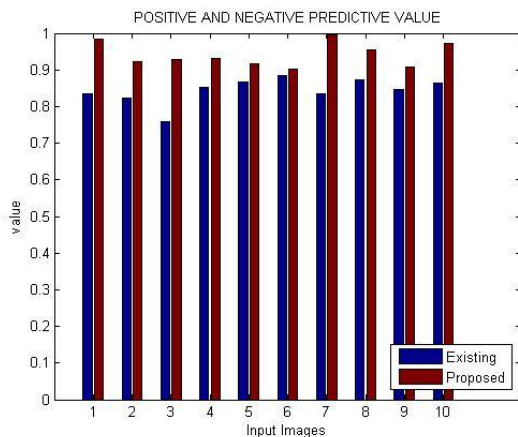

Fig.6. Comparative analysis of parameter PPV for 10 input images

5) FALSE DETECTION RATE (FDR)

The false discovery rate (FDR) is the expected proportion of false positives amongst the declared significant results.

Table 5 shows the comparison of FDR values for the existing and proposed algorithm. T, the value of proposed FDR is lower as compared to existing FDR for the 10 input images, thus it shows better result than the existing algorithm.

Table 5. The results of parameter FDR for 10 input images

Image Name	Existing FDR	Proposed FDR
Img1	0.1659	0.086951
Img2	0.1779	0.010055
Img3	0.2413	0.020098
Img4	0.1483	0.032047
Img5	0.1324	0.008978
Img6	0.1153	0.025696
Img7	0.1643	0.081974
Img8	0.1267	0.088262
Img9	0.1535	0.055885
Img10	0.1364	0.076124

Fig.7 shows the graph of comparison of FDR values for the existing and proposed algorithms. In this graph, the FDR values of existing images are compared with the values of proposed images. The blue color in graph represents the FDR value calculated using Gabor filter bank, maroon color represents the FDR value calculated using hybrid trilateral Gabor filter. Value of FDR is lower thus shows that proposed algorithms shows better result.
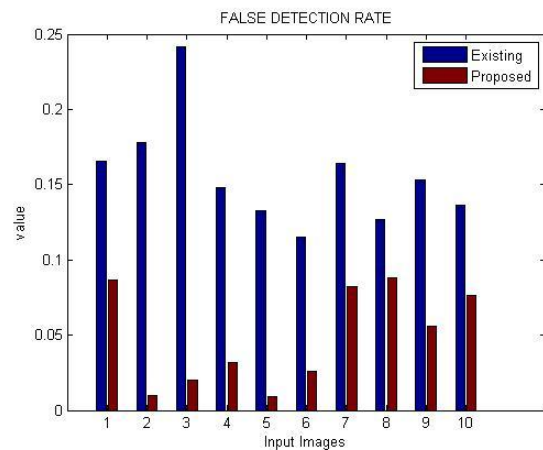

Fig.7. Comparative analysis of parameter FDR for 10 input images

VII. Conclusion

Image segmentation technique is a method to partition an electronic digital image into numerous sub-images. Eye disorders are a common problem amongst many individuals. Identification of diabetic retinopathy lesions, such as exudates, in fundus images can help in early diagnosis of a problem. This technique shows better results however it is suffers from the effect of the noise. So a hybrid Gabor filter bank with trilateral based filtering technique is proposed in this dissertation to enhance the accuracy rate and to overcome the problem of noise from the images. The experimental results show that the Gabor filter bank based fundus segmentation has shown quite effective results while detecting the exudates in fundus images and enables us to detect exudates even

in highly corrupted noisy images. This work has not considered the effect of low intensity in digital images. So in near future we will evaluate the effect of low intensity on digital images. Also some evolutionary optimization techniques will be used in future.

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