Automated System for Macula Detection in Digital Retinal Images

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Abstract—**In the field of medicines, medical image processing plays a vital role to detect the abnormalities of eye or eye diseases like glaucoma and diabetic retinopathy. Macular degeneration is one of the medical conditions that affect the vision of elder people. If not detected in early stages it causes loss of eye sight. This paper presents an automated system for the localization and detection of macula in digital retinal images. In this paper, macula is first localized by making use of localized optic disc centre and enhanced blood vessels. Finally macula is detected by taking the distance from center of optic disk and thresholding, then combining it with enhanced blood vessels image to locate the darkest pixel in this region, making clusters of these pixels. The largest pixel is located as macula. This methodology is tested on publically available DRIVE and STARE database of retinal images which enable us to check the results of macula localization and detection. Our algorithm performs well in localizing and detecting macula on these databases.**

I. INTRODUCTION

Now days, diabetic retinopathy is a key reason for the blindness in elder age people. Patients who are suffering from diabetes are more likely to have eye disease but the main threat to eye sight is effect on retina. [1] To detect the diabetic retinopathy in diabetic patients, retinal images should be analyzed. Retinal images are usually known as Fundus images are at the back of eye. Analysis of retinal images leads us to detect different diseases like retinopathy, glaucoma and macular degeneration. Diabetic retinopathy that can damage the retina is usually occurring due to diabetes mellitus complications which can lead to blindness if not treated in early stages [2]. Retina is usually red in color due to rich blood supply in it and it is responsible for the bright vision. Ophthalmologists analyze the retina by considering optical disk, macula and blood vascular as important anatomical part of retina. Macula is the central part of retina that is responsible for the sharp central vision [3]. Ophthalmologists use these information to diagnose and for the treatment of that disease. Optical disk detection is an essential step to detect the macula because macula is the darkest region present in neighborhood of optical disk. And blood vessels detection can help in detection of macula as it is our prerequisite requirement to detect macula. More over retinal vascular extraction is used in some other application related to security application like personal identification [4]. The main concern of this paper is to detect macula. It is the highly sensitive area of the retina. Patients suffering from diabetic retinopathy have a special scenario of macular oedema, cause by the leakage of blood in blood vessels in macula region. To detect the macula is the most important step for the treatment of macular oedema, if detected earlier it can be treated by laser [5]

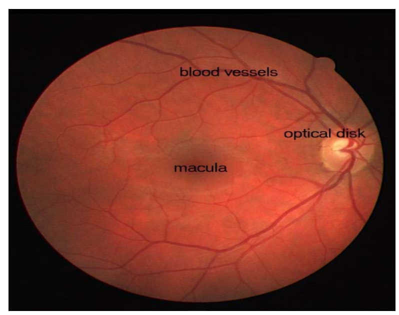


Fig.1: Retinal image

Different techniques are given in literature for macula detection. In [6], macula is detected using morphological properties of eye. [7] Presents the methodology to detect macula using edge detection and region growing techniques. [8] Uses a novel technique for localization of optic disk, macula and fovea. Robust shade correction operation extract the optical disk and adaptive thresh holding is applied to get macula. In [9], image relative subtraction approach is applied on Fundus images to localize macula and fovea. [10] Represents a technique for detection of anatomical structure of Fundus images by first generating mask then image quality is enhanced by histogram and canny edge detection. Then Hausdorff-based matching is applied on optical disk and macula is localized by pyramidal decomposition. Optical disk, fovea and blood vessels are extracted from colored digital fundal images using PCA in [11].

For the detection of macula, method we propose here include first of all the localization and detection of optical disk. Optical disk is the brightest region of retina yellowish in color. Optical disk is localized by applying Hough transform. Center of optical disk is needed for detection of macula as macula lies in neighborhood of optical disk. Next step toward the detection of macula is blood vessels enhancement. In this paper we present a technique to extract blood vessels using 2 D Gabor wavelet. Finally macula is detected by finding the distance from the center of the optical disk, thresholding and then finding the darkest area as macula is the darkest region.

This paper is composed of four sections. Proposed method is described in section 2 including step by step methodology. Experimental results are given in section 3 and followed by conclusion in section 4.

II. PROPOSED METHOD

The method proposed in this paper consists of three main stages. Systematic diagram of proposed technique is given in figure 2.

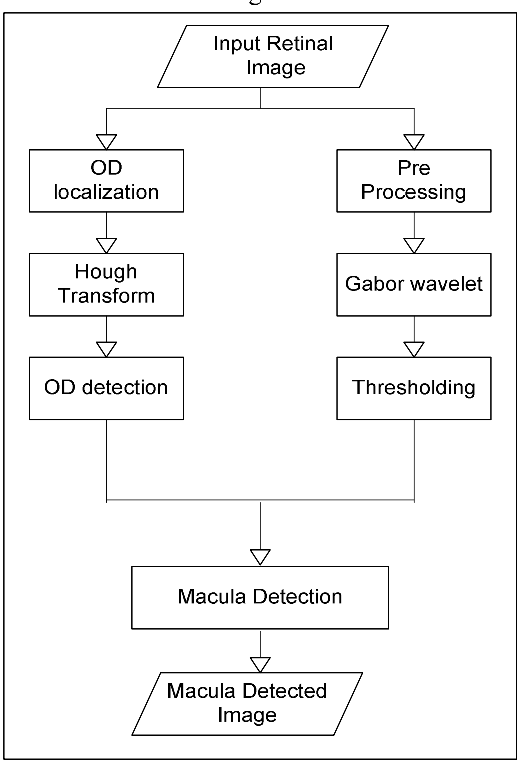


Fig. 2: Systematic diagram of proposed technique

A. Optic Disk Detection:

First step toward macula detection is to localize and detect the optic disk, a spot where optical nerves leave the retina. Following are the steps toward the localization and detection of Optical disk.

- Optical disk is first localized by converting the original retinal image into green channel.
- An averaging filter of 31x31 is applied on green channel to remove noise from image using (1).

$$\overline{g}(x, y) = \frac{1}{961} \sum_{i=1}^{961} g_i(x, y) \qquad (1)$$

- As OD is the bright portion of retina so to localize gray level pixels histogram of image is calculated to localize the gray pixel from background values using (2).

$$s_k = \max(T(r_k)) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n} \qquad 2)$$

$$k = 0,1,2,..., L-1$$

- OD is localized then ROI is calculated to detect OD.
- From ROI optical disk is extracted by applying Hough transform [12]. Hough transform is used in this method due to its ability to extract the isolated features from an image in a particular shape. OD is circular in shape so a parameterized equation of circle is applied that is given as

$$(x-a)^2 + (y-b)^2 = r^2 \qquad 3)$$

- Canny operator is used here for edge detection in Hough transform with parameter $\sigma = 1$.
- Optical disk is then detected and circle is plotted on it and center of OD that can be used for macula detection.

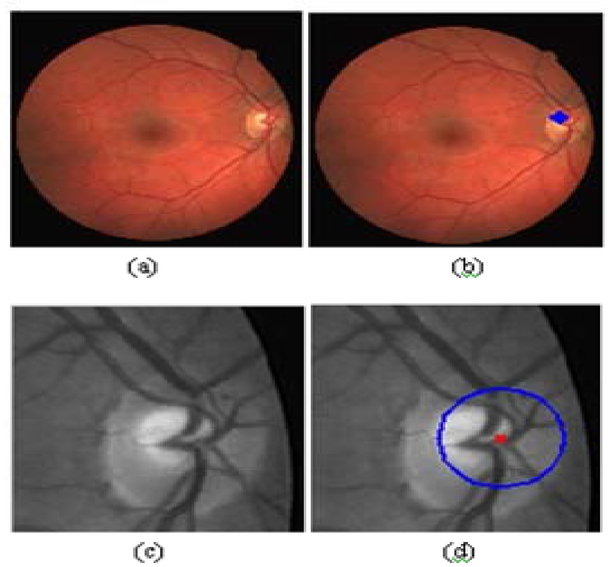
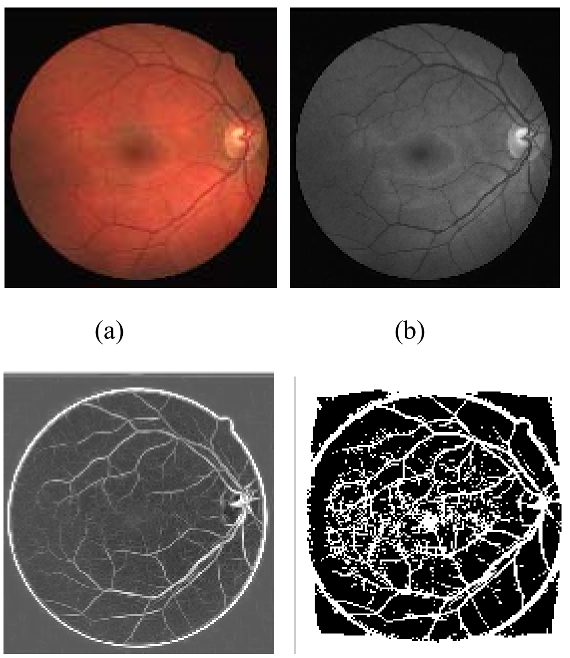


Fig 3. Optical Disk Localization and Detection: a) Original Retinal Image, b) OD Localization, c)ROI, d) OD Detection

B. Blood Vessel Enhancement and Segmentation:

Blood vessels enhancement is an important step toward the detection of macula. Blood vessels enhancement is also useful for screening vessels and specialist can easily diagnose the disease. In proposed technique blood vessels enhancement is done using 2D Gabor wavelet transform [13]. 2D Gabor wavelet is useful to enhance less visible or thin vessels. At specific frequency 2D Gabor wavelet is used for feature detection and fine tuning of vessels. Steps for Blood vessels detection are given below:

- A retinal image is taken as input and converts it into green channel as vessels appear more contrast in this channel.
- Inverting resulting image and apply Fourier transform on it.
- Wavelet is calculated and 2D Gabor wavelet is applied on Fourier transform image.
- Transfer it back to spatial domain by taking inverse Fourier transform.
- Vascular pattern of retinal image is computed. As vessels are brighter so maximum value is calculated from histogram.
- Background is enhanced and appears more contrasted. And finally apply adaptive threshold to separate the vessels from the rest of image [13].



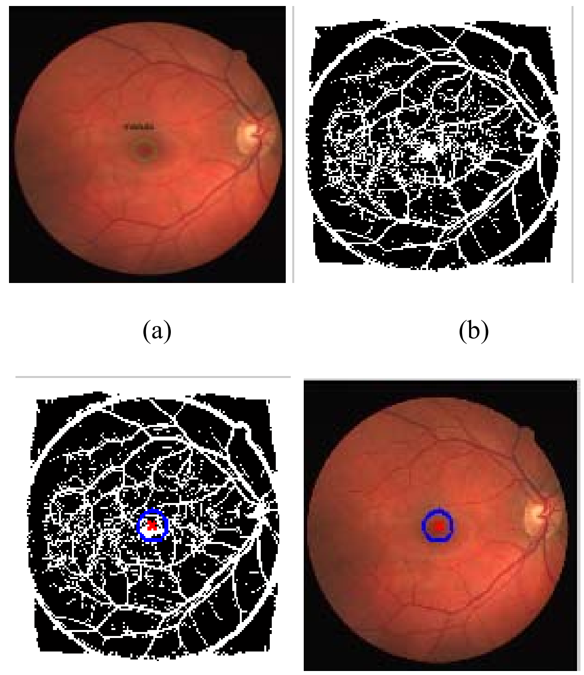
(a) (b) (c) (d)

Fig. 4. Blood Vessels Enhancement. (a) Input retinal image. (b) Green channel image. (c) Gabor wavelet enhanced image. (d) Threshold blood vessel image.

C. *Macula Detection*

Macula is the most essential part of the retina that is responsible for the central vision of eye. Macula is the darkest region of the retinal images. Algorithm for the detection of macula includes following steps:

- Threshold image is taken from Blood vessels enhancement.
- Find the maximum value among the image in front of optical disk by taking the center point of optical disk from detection of optical disk.
- Getting the mean of these maximum value and plot them on threshold image.
- In addition, a circular macula region is first manually labeled as shown in Fig. 5 (a) and the macula is deemed to be correctly located if the detected macula lies within the circular region.
- Finally that macula region is plotted back to the original image where it shows the macula being detected.



(a) (b) (c) (d)

Fig. 5. Macula Detection. (a) Manually labeled retinal image. (b) Threshold image. (c) Macula localization. (d) Macula detection.

III. EXPERIMENTAL RESULTS

To evaluate the performance of proposed algorithm, a dataset of 60 images are used. Evaluation is applied on DRIVE (Digital Retinal Images for Vessel Extraction) and STARE (Structured Analysis of Retina) databases that is publically available. 40 images of size 768x584, each pixel having eight bits are included in DRIVE database while STARE database contain 20 images, each of size 605x700 per pixel having 24 bits. This test set of 60 images are used for the performance evaluation of macula detection using proposed algorithm. For the verification of macula detection results, macula is manually labeled by the ophthalmologists for each image. The manually segmented macula by human observer is used as ground truth. The true positive fraction is the fraction of number of true positive (pixels that actually belong to macula) and total number of macula pixels in the retinal image. False positive fraction is calculated by dividing false positives (pixels that don't belong to macula) by total number of non macula pixels in the retinal image. Average accuracy shows how much accurate the particular technique is. Standard deviation shows how much it deviates from the ground truth. Table 1 summarizes the results of several techniques [6], [7], [8], [9] using drive database. It shows results in terms of average accuracy and standard deviation. This table clearly shows that macula detection using proposed algorithm gives better results. Table 2 summarizes the results of these techniques [6], [7], [8], [9] using STARE database.

TABLE I: MACULA DETECTION RESULTS (DRIVE DATASET)

Technique	**Average Accuracy**	**Standard Deviation**
Anantha et. al	0.967	0.0247
Huiqi et. al	0.9351	0.0333
Sekhar et. al	0.9516	0.0329
Jeetinder et. al	0.9480	0.0298
Proposed technique	**0.987**	**0.0133**

TABLE II: MACULA DETECTION RESULTS (STARE DATASET)

Technique	**Average accuracy**	**Standard deviation**
Anantha et. al	0.971	0.0237
Huiqi et. al	0.942	0.0310
Sekhar et. al	0.965	0.029
Jeetinder et. al	0.9521	0.035
Proposed Technique	**0.991**	**0.021**

Figure 6 shows the result of proposed technique on different input retinal images from DRIVE and STARE.

IV. CONCLUSION

In this paper, an automated system is proposed for the detection of macula using optic disk and blood vessels. A dataset of 60 images are used to check the accuracy of the proposed algorithm. The results of given technique can satisfy our required goal of detection of macula. This technique is very useful in medical imaging department for the treatment of diabetic retinopathy patients. Our future work will be to detect the abnormalities of macula.

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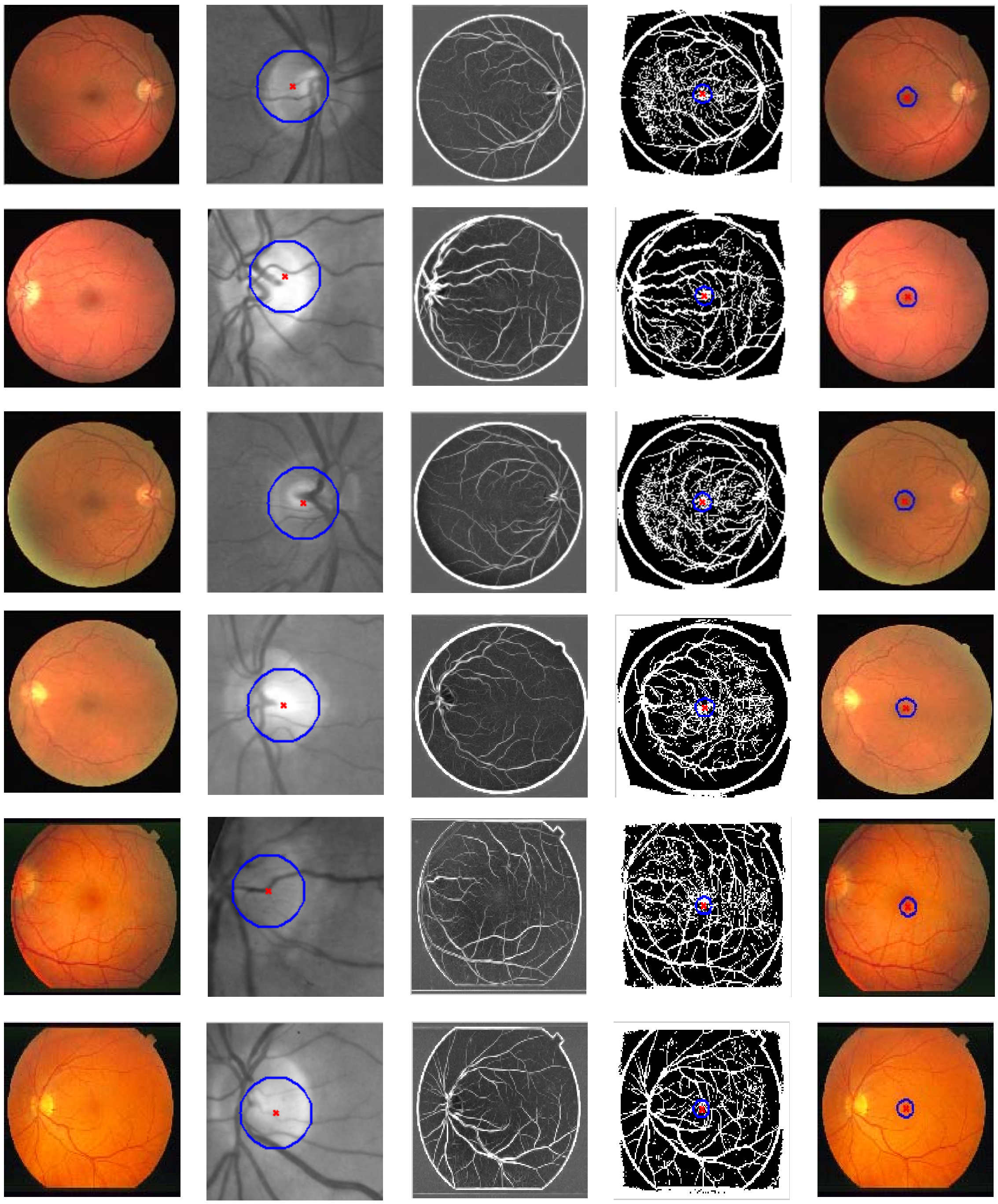

(a) (b) (c) (d) (e)

Fig.6. Experimental Results: a) Original Images from DRIVE and STARE, b) OD Detection, c)Vessel Enhancement, d) Macula Localization, e)Macula Detection