Fovea Region Detection in Noisy Fundus Retinal Image Using Wavelet Transform And Clustering

Varalekshmi V.R., Dr.P.Janardhanan

Abstract – Analysis of retinal image is one of the difficult task in medical image processing. Retinal fundus images are normally manually graded by specially trained clinicians in a time consuming and resource intensive process. This paper aims in presenting a new method that automatically detect the fovea region in retinal fundus image in noisy conditions especially in the case of transmission. In the proposed method a special case of impulse noise is taken and fuzzy based denoising is done and the blood vessel structure is obtained using wavelet transform and finally the fovea is localized using the fuzzy c means clustering algorithm. This method has been implemented in MATLAB and tested in the publically available DRIVE database and results show that this method is applicable in case of low noise variances.

Index Terms – Fovea, Fundus image, Wavelet transform, Fuzzy c means clustering.

I. INTRODUCTION

The fovea is the most important part of the eye, located in the center of the macula region of the retina. Usually this fovea zone is approximated to a circle of radius 200 micron[1]. The fundus images are most commonly used by ophthalmologists to monitor the progression of disease. They are captured using devices called ophthalmoscopes [3]. Normally these images are manually graded by specially trained clinicians in a time consuming and resource intensive process.

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A typical retinal fundus image with its features labeled is shown in figure 1. The central region called the macula is a circular area measuring about 4mm to 5mm in diameter. A small depression in the centre of the macula is called fovea. The optic disc is the entry and exit site of blood vessels and optic nerve fibres responsible for transmitting electrical impulses from the retina to the brain.

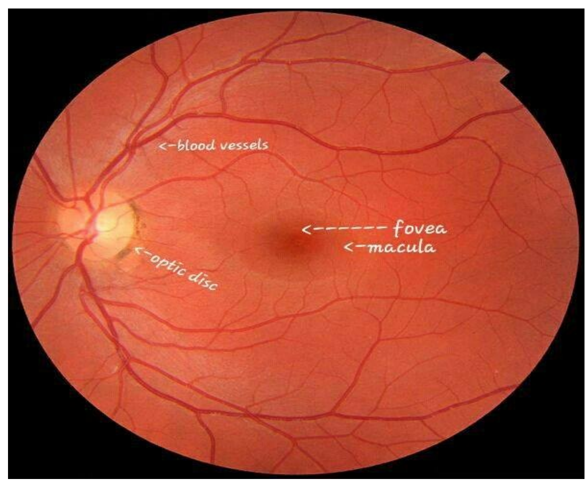

Fig 1 : Retinal Fundus Image

In this paper detection of the fovea region in noisy conditions is considered. Fuzzy based denoising is done here. Wavelet transform and fuzzy c means clustering is used for fovea detection. This method is based on the structure of the blood vessels around the macula region. A little bit of information about the optic disc is also used with the structure of the blood vessels to accurately determine the fovea region. The proposed method is divided into three sections. In the

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first stage denoising is done using fuzzy denoising. In the second stage the blood vessels are determined using wavelet transform. Geometrically fovea is said to be located at a distance 2.5 times the diameter of the optic disc [2]. This information along with the vessel structure is used in the third stage to localize the fovea region accurately by using fuzzy c means clustering.

II. RELATED WORK

Retinal image analysis is a complicated task particularly because of the variability of the images in terms of the color, the morphology of the retinal anatomical pathological structure and the existence of particular features in different patients, which may lead to an erroneous interpretation. This has led to the development of many retinal image analysis methods.

Various attempts were made for the successful detection of fovea region. In one of them S. Samanta et.al [1] have used certain morphological operations and sliding window technique to localize the fovea region. In this the macula region was approximated by a circle and its centre was found as the fovea region. Sinthanayothin et al. [2] choosed fovea as the position of maximum correlation between a model template and the intensity image, obtained from the intensity hue saturation transformation. They have used a template of size 40 x 40 with Gaussian distribution. S. Sekhar [3] introduced a method based on spatial distribution of macula lutea. This method heavily depends upon the success of the optic disk localization. In fact many techniques first detect the blood vessels and then the optic disk (OD) to locate the fovea.

Many methods are there in the literature for blood vessels detection. S. Chaudhury et al. [4] modeled the cross section of a vessel in a retinal image by a Gaussian shaped curve and the detected using a two dimensional matched filters. The highest Matched Filter Response (MFR) is selected for each pixel and is typically thresholded to provide a vessel image. MFR method is effective when used in conjunction with additional processing techniques. Scheme based on active contour model [5], mathematical morphology [6] and curvature analysis have also been developed by researchers.

There are various works reported in the literature related to OD segmentation. Foracchia et al. [7] have detected the position of the OD based on the preliminary identification of the main retinal vessels. Hajer et al. [8] have used water snake to localize the OD.

III. PROPOSED METHOD

A. Fuzzy based de-noising

Suppose if we need to transmit the fundus image to far places in case of emergency it can happen that noise affects this image. Thus we need to denoise it so as to retrieve the original image for diagnosis. Here a case of random impulse noise is taken. First the degree of noise of each pixel is estimated. Certain fuzzy rules are used for by taking a 3x3 window surrounding that pixel.

If $|I(x,y) - I(x+k, y+k)|$,where $I(x,y)$ is the intensity of the present evaluated pixel and $I(x+k, y+k)$ is the intensity of the pixels in the 3x3 nieghbourhood is a large positive value then we say that particular pixel is noisy. Again we check for $|I(x,y,R) - I(x,y,G)|$, $|I(x,y,R) - I(x,y,B)|$, where $I(x,y,R)$, $I(x,y,G)$, $I(x,y,B)$ are the red green and blue components of the pixel respectively.

All the noisy pixels are then filtered by using median filter to retrieve the fundus image.

B . *Detection of blood vessels*

Blood vessels appear as network like structure and if we look the fundus retinal image carefully we can see that there is no blood vessels around the macula region. This feature is used to find the fovea region. The wavelet transform algorithm is used.

An image signal can be analysed by passing it through an analysis filter bank followed by a decimation operation.

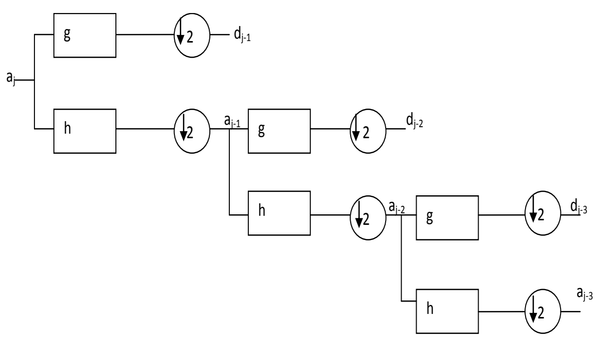


Fig 2 : Multilevel decomposition

When a signal passes through these filters , it is split into two bands. The low pass filter, which corresponds to an averaging operation, extracts the coarse information of the signal. The high pass filter, which corresponds to a differencing operation, extracts the detail information of the signal. The output of the filtering operations is then decimated by two.

A two dimensional transform (see figure 3) can be accomplished by performing two separate one dimensional transforms. First, the image is filtered along the x dimension using low pass and high pass analysis filters and decimated by two. Low pass filtered coefficients are stored on the left part of the matrix and high pass filtered on the right. Then, it is followed by filtering the sub-image along y-dimension and decimated by two. Finally we have split the image into four bands denoted by LL, HL, LH and HH after one level decomposition. This process is again repeated to obtain the third level decomposition as seen in figure 3.

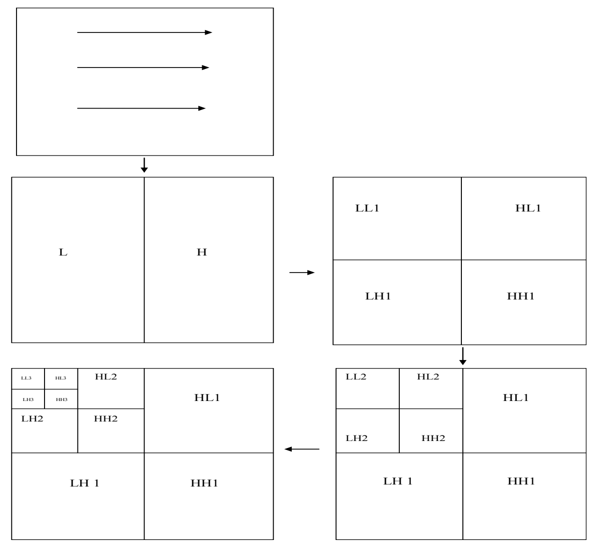


Fig3 : Steps in pyramidal decomposition of an image.

Here since the blood vessels are of high frequency, the low-low level (LL3) is neglected and the rest is reconstructed to detect the blood vessels. The reconstruction of the image can be carried out by the reverse procedure of decomposition. This process is repeated until the desired blood vessel image is fully reconstructed.

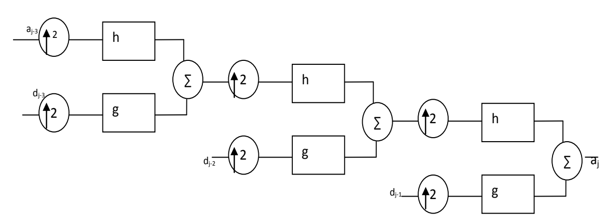


Fig 4 : Multilevel reconstruction

C. *Optic Disk Detection*

After detecting the blood vessels, inorder to detect the fovea the information about the optic disk needed. Thus it becomes essential to detect OD. First the center of the optic disk is found by using the following formula:

$$C_x = \sum_{i=1}^{k} \frac{x_i}{k}, \quad C_y = \sum_{i=1}^{k} \frac{y_i}{k} \qquad (1)$$

where x_i and y_i are the coordinates of pixels in the blood vessel image an k is the number of pixels set to zero. Next it is found if this center point is in the left or in the right. For that the maximum number of columns in the image is found as follows: If $C_y >$ 0.5 x maximum column, Then the OD center is in the right side. Else the center is in the left side. Next boundary of the optic disk is found by using Fuzzy C means clustering algorithm.

D.*Fuzzy C- Means Clustering Algorithm*

This algorithm assigns membership to each data point corresponding to each cluster center on the basis of distance between the data point and the cluster center. More the data is near to the cluster center more is its membership towards the particular cluster center. After each iteration membership and cluster centers are updated. Main objective of fuzzy c-means algorithm is to minimize:

$$J(U,V) = \sum_{i=1}^{n} \sum_{j=1}^{c} (\mu_{ij})^m \left\| x_i - v_j \right\|^2 \qquad (2)$$

where n is the number of data points. m is the fuzziness index m € [1, ∞]. c represents the number of cluster center. 'µij' represents the membership of i^{th} data to j^{th} cluster center. J is the objective function. $||x_i - v_j||$ is the Euclidean distance between i^{th} data and j^{th} cluster center. Thus the Algorithmic steps for Fuzzy c-means clustering are as follows :

Let X = {$x_1, x_2, x_3 ..., x_n$} be the set of data points and V = {$v_1, v_2, v_3 ..., v_c$} be the set of centers.

1) Randomly select c cluster centers.

2)Calculate the fuzzy memebership μ_{ij} using :

$$\mu_{ij} = 1 / \sum_{k=1}^{c} (d_{ij} / d_{ik})^{(2/m-1)} \qquad (3)$$

3) Compute the fuzzy centers v_j using:

$$v_j = (\sum_{i=1}^{n} (\mu_{ij})^m x_i) / (\sum_{i=1}^{n} (\mu_{ij})^m), \forall j = 1, 2, ...c \qquad (4)$$

4) Repeat step 2) and 3) until the minimum J value is achieved or $||U^{(k+1)} - U^{(k)}|| < \beta$.

where, k is the iteration step. β is the termination criterion between [0, 1]. U = $(\mu_{ij})_{n*c}$ is the fuzzy membership matrix. vj represents the j^{th} cluster center. dij represents the Euclidean distance between i^{th} data and j^{th} cluster center.

Once the center and boundary of the OD is found the diameter (d) of the optic disk is found. And then a point Q is located at a distance 2.5 x d from the optic disk center towards the left if OD center is in the right side and towards the right if OD center is in the left side.

E. *Fovea Localization*

Fovea is localized by using sliding window technique and Fuzzy C means Clustering algorithm. Sliding window of small size at the point Q is taken and a small region belonging to the fovec region is identified. Similar regions are identified by the above mentioned Fuzzy C means clustering algorithm. Then the geometrical centroid of the cluster is found to get the fovea region.

IV. EXPERIMENTAL RESULTS

The proposed method of fovea detection was tested on a publically available DRIVE database [10].DRIVE is a database assembled in Netherlands and consists of 40 images of size 565 x 585 divided into test and training images. The error rate corresponding to different values of noise variance is plotted in graph below. It can be seen that for only for high noise variance the error rate is high and this method is effective in low noise variances and this portion of the graph can be used for diagnosis purposes. Some results of the DRIVE database is shown in the figure 4.

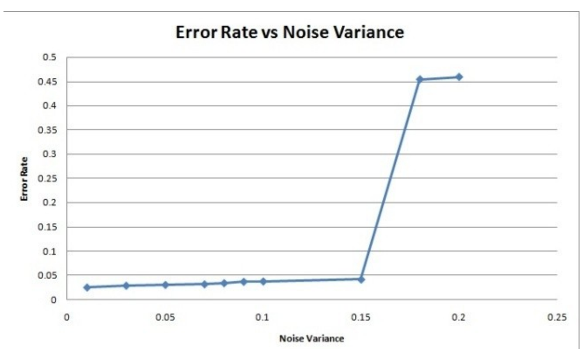
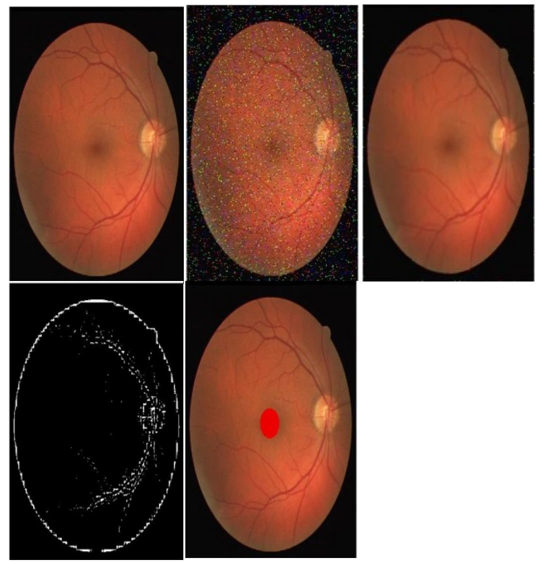


Fig 4. Plot of error rate vs noise variance.

V. CONCLUSION

A new and efficient method to localize the fovea in noisy retinal fundus image has been described. Fuzzy based denoising is done and Wavelet transform, sliding window technique and Fuzzy C means clustering algorithm is used here to localize fovea region successfully. In future the extracted fovea and macula region can be used for diagnostic purposes in detecting diseases.



(a) (b) (c)

(d) (e)

Fig 5 : Experimental results (a) color fundus image, (b) noisy image (c) denoised image (d) blood vessels, (e) Fovea region.

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