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Optic Disk Localization in Retinal Images using Histogram Matching

1 Introduction

Retina is the innermost layer of the eye which can be visualized using adequate apparatus such as fundus camera. The two main structures used in retinal image analysis are blood vessels and optic disc. Optic disc is the brightest region in the retinal image and the blood vessels originate from its center. Optic disc is a key reference for recognition algorithms, blood vessels segmentation, and diagnosing some diseases such as diabetes. Histogram is the main character of each image and histogram-based methods are used as the first step of most pre-processing methods to improve the contrast and illumination of retina images. One of the main drawbacks of uneven illumination in retina images and their poor quality is the inability to analyze the optic disc. Applying illumination equalization (histogram equalization, histogram specification, and other normalization methods) as pre-processing methods to retina images considerably improves the contrast, and illumination for further analysis tasks such as optic disc localization and vessel segmentation. In this article, we propose a new method based on the histograms of some optic discs extracted from retinal images. For this purpose, we extract the optic disc of the first four retinal images in DRIVE data set. Then, we calculate the average of histograms for each color component as template to localize the center of optic disc.

2 System Analysis

2.1 Existing System

2.1.1 Automated identification of diabetic retinal exudates and the optic disc

This method is based on template matching for localizing the center of optic disc. In this algorithm, some of retinal images in dataset were used to create a template and the correlation between each image and template is computed. The point which has the maximum correlation value is selected as the center of optic disc.

2.1.2 Optic disc detection from normalized digital fundus images by means of a vessels direction matched filter

This method uses directional pattern of the retinal blood vessels to localize the center of optic disc. Hence, a simple matched filter was proposed to match the direction of the vessels at the optic disc vicinity. The retinal vessels were segmented using a simple and standard 2D Gaussian matched filter. Consequently, vessels direction map of the segmented retinal vessels was obtained using the same segmentation algorithm. Then, the segmented vessels were thinned and filtered using local intensity to represent the optic disc center candidates. The Gaussian matched filter was resized in four different sizes, and the difference between the output of the matched filter and the vessels directions was measured. The minimum difference provided an estimate of the optic disccenter coordinates.

2.1.3 Automatic location of optic disc in retinal images

This is a new method to localize optic disc center. The candidate regions were first determined by clustering the brightest pixels in retinal images. This strategy can only work when there is no abnormality in the retina image. Principal component analysis was applied to these candidate regions. The minimum distance between the original retinal image and its projection onto disk space was located as the center of optic disc.

2.1.4 Detection of the optic nerve head in fundus images of the retina with Gabor filters and phase portrait analysis.

In this method, optic disc center was localized based on the property that it appears as the focal point of the blood vessels in retina mage. The method includes detection of the blood vessels using Gabor filters and detection of peaks in the node map via phase portrait

analysis. In the second method, edge detection using the Sobel operators and detection of circles using the Hough transform were employed to localize optic disc and its center.

2.1.5 Automated optic disc detection in retinal images of patients with diabetic retinopathy and risk of macular edema.

This method uses two independent methodologies to detect optic disc in retina images. Location methodology obtains a pixel that belongs to the optic disc using image contrast analysis and structural filtering techniques. Then, a boundary segmentation methodology estimates a circular approximation of the optic disc boundary by applying mathematical morphology, edge detection techniques, and the circular Hough transform.

2.1.6 Automatic localization and boundary detection of optic disc using implicit active contours

This method employs a new approach for the automatic localization and accurate boundary detection of the optic disc. Iterative thresholding method followed by connected component analysis was employed to localize the approximate center of the optic disc. Then, geometric model based on implicit active contour model was applied to find the exact boundary of the optic disc.

2.1.7 Detection of optic disc in retinal images by means of a geometrical model of vessel structure.

This method presented a new technique for localizing the optic disc center in retinal images. The method was based on the preliminary detection of the main retinal vessels. All retinal vessels originate from the optic disc and their path follows a similar directional pattern (parabolic course) in all images. To describe the general direction of retinal vessels at any given position in the image, a geometrical parametric model was proposed, where two of the model parameters are the coordinates of the optic disc.

2.1.8 Identification of the optic nerve head with genetic algorithms

This method uses genetic algorithm method to obtain an ellipse approximating the optic disc in retinal images. A set of hypothesis points were initially obtained that exhibited geometric properties and intensity levels similar to the optic disc contour pixels. Then, a

genetic algorithm was used to find an ellipse containing the maximum number of hypothesis points in an offset of its perimeter, considering some constraints.

2.2 Proposed System

Most of the methods for localizing optic disc fail when pathological regions exist in retina images. Some other algorithms suffer from high computational cost. Here, a new robust method for localizing the center of optic disc in presence of pathological regions is proposed. Since in this method pre-processing algorithms such as segmentation are not used, the computational cost is drastically reduced with respect to some counterparts.

In this method, similar to [8], we use a number of retinal images to create a template for optic disc. However, instead of creating an image as template, we construct three histograms as template, each corresponding to one color component. At the first step to decrease the effect of noise, we apply an average filter with the size of 6 6 pixels to retina images. Then, we use a window with the typical size of the optic disc (80 80 pixels) to extract the optic disc of each retinal image. In the next step, we separate color components (red, blue, and green) of each optic disc to obtain the histogram of each color component. Finally, the mean histogram of each color component for all retinal image samples is calculated as template. Histogram is a graph showing the number of pixels at each different intensity value found in an image. As illustrated before, we use the histogram of each three channels (red, green, and blue) as template for optic disc localization. Then, to decrease the effect of pathological regions and exudates that are high-bright regions like optic disc, we use the histogram of pixels which has the intensity value lower than 200. Therefore, we decrease the effect of high intensity regions that are common in optic disc, pathological regions and exudates and the role of vessels for optic disc localization will increase.

Template Matching: Up to now, we determined three histograms as template for localizing the center of optic disc. For localizing the center of optic disc, at first step to decrease the effect of noise an average filter with the size of 6 6 pixels is applied to retina image. Then, an 80 80 pixels window is moved through retinal image. In each moving window, we separate the channels (red, blue, and green) and obtain the histogram of each channel. Then, we calculate the correlation between the histogram of each channel in the moving window and the histograms of its corresponding channel in template. For this purpose, we can use correlation or cross-correlation function to obtain the similarity of the two histograms; however, the optic disc centers obtained using these methods are

not accurate. The function used for correlation between two histograms is expressed in the following equation:

$$c = \frac{1}{(1 + \sum_i (a_i - b_i)^2)}$$

Where a and b are two histograms that we want to calculate their correlation and c is the result of the correlation.

Therefore, if the two histograms (a and b) are similar, then $\sum_i (a_i - b_i)^2 = 0$ and $c \approx 1$, else and $c << 1$. Therefore, using above equation, we can calculate the correlation between two histograms and the result of correlation is in the range of [0 1].

For each moving window, we obtain three values as the results of correlation between the histograms. The result of histograms matching is computed as the weighted sum of the three obtained values:

$$c(i,j) = t_r \times c_r + t_g \times c_g + t_b \times c_b$$

. where (i, j) is the center of moving window. c_r , c_g , and c_b are the results of correlation for three channels (red, green, and blue) and t_r, t_g, and t_b are weights used for each channel. In the second equation, we can use different weights for c_r , c_g , and c_b. The green channel has the highest weight because the contrast of the green channel is higher than red and blue channels. In some retinal images, blue channel is noisy; therefore, to decrease the effect of blue channel on our localizing method, we determine the lowest weight for blue channel. The best weights that result high accuracy rate for optic disc localizing method are $t_r = 0.5$, $t_g = 2$, and $t_b = 1$. To localize the center of optic disc, we apply thresholding on the correlation function C(i,j). For finding the best threshold, we did a global scanning of different values and the best equation to determine the threshold (Th) was obtained as follows.

$$Th = 0.5 \times max(C)$$

where max(C) is the element of C with the maximum value. Therefore, the threshold value for each image is half of the maximum value of the correlation function. The center of gravity of the binary image obtained from thresholding is considered as the center of optic disc.

2.2.1 Scope of implementation

Recently many algorithms have been proposed to localize Optical DIsc (OD).These algorithm successes are based on a seed point inside the OD.OD localization is a first key processing component in many algorithms designed for the automatic extraction of retinal abnormalities, such as drusen, exudates, microaneurysms, and hemorrhage. The OD was also used as an initial point for retinal vasculature tracking methods. Automatic retinal image analysis is an important screening tool for easy detection of eye diseases like diabetic retinopathy, glaucoma. The manual method graded by clinicians is a time consuming and resource-intensive process. Automatic retinal image analysis provide an immediate detection and characterization of retinal features prior to specialist inspection. Current OD localization techniques suffer from impractically-high computation times (few minutes per image). In this work, we present a fast technique that requires less than a second to localize the OD. algorithms. We use optic disc of the first four retinal images in DRIVE dataset to extract the histograms of each color component. Then, we calculate the average of histograms for each color as template for localizing the center of optic disc. The DRIVE, STARE, and a local dataset including 273 retinal images are used to evaluate the proposed algorithm.The novelty of this method is to reduce the dimensional space based on image resolutions thus, enhances to speedup of the OD localization process.

2.2.2 Aim of the implementation

Recently many algorithms have been proposed to localize OD. These algorithm's success are based on a seed point inside the OD. The OD localization is useful in the following applications.

1. Localizing and segmenting retinal structure such as blood vessels, macula and fovia and also other anatomical structure such asmicroaneurysms, hemorrhage, drusen,etc.

2. To classify left and right eyes in macula-centered retinal images.

The manual methods of localization graded by clinicians are time consuming and they are all a resource-intensive process. The automatic detection process helps ophthalmologists in taking immediate decision regarding retinal image analysis.Normally, retinal images have a clear structure so the localization process is very simple. The abnormal images are not clear so the localization here is a challenging task. The OD localization methods are categorized into two types,

1.Appearance-based methods

2.Model-based methods

Appearance-based methods consider OD as the brightest objects within the retinal images. These methods include techniques such as approximate nearest neighbour field, directional window, Harris corner detector, histogram matching, luminance minimization and line operator. These methods are very simple and achieved high success rates in normal images. One of the above mentioned methods the,i.e, the histogram method is being used here in this project.

2.2.3 Project Modules

In this method, we use a number of retinal images to create a template for optic disc. However, instead of creating an image as template, we construct three histograms as template, each corresponding to one color component. At the first step to decrease the effect of noise, apply an average filter with the size of 6 6 pixels to retina images. Then, we use a window with the typical size of the optic disc (80 80 pixels) to extract the optic disc of each retinal image. In the next step, separate color components (red, blue, and green) of each optic disc to obtain the histogram of each color component. Finally, the mean histogram of each color component for all retinal image samples is calculated as template.

Histogram is a graph showing the number of pixels at each different intensity value found in an image. As illustrated before, we use the histogram of each three channels (red,green, and blue) as template for optic disc localization. Then, to decrease the effect of pathological regions and exudates that are high-bright regions like optic disc, we use the histogram of pixels which has the intensity value lower than 200. Therefore, we decrease the effect of high intensity regions that are common in optic disc, pathological regions and exudates and the role of vessels for optic disc localization will increase. the following is a list of modules that have been used:

1. Automated Detection of Abnormalities

This group aims at identifying the abnormalities in the retina in order to assist ophthalmologists to diagnose, predict and monitor the progress of, the disease that a patient suffers from.

- **Disease diagnosis:** refers to detecting the abnormal symptoms in the retina such as exudates, aneurysms and hemorrhages in order to diagnose diseases that affect the eye like diabetic retinopathy, glaucoma, macular edema, etc.
- **Disease prediction:** refers to observing the retinal disorders that may lead to other pathological conditions or vision loss (blindness).
- **Disease progress monitoring:**concerned with comparing the changes of the states in the eye fundus at particular intervals of time in order to observe either the improvement or deterioration of some disease.

2. Automated Segmentation of Landmarks

The eye fundus is being segmented in order to locate and isolate the retinal landmarks, namely the optic disc, macula, fovea, veins and arteries.

- **Optic disc segmentation:** the optic disc is a key landmark in retinal images, and shows changes related to diseases including glaucoma and diabetic retinopathies. The optic disc also serves as a landmark in order to locate other fundus features such as the macula and blood vessels as mentioned before.
- **Macula and fovea segmentation:** locating the macula is important in detecting related diseases such as macular degeneration and macular edema.
- **Vascular segmentation (veins arteries):** analyzing the blood vessels in the retina is important for detection of diseases of blood circulation such as diabetic retinopathy.

2.3 Block diagram

This work proposed a fast OD localization method with less computation time and high success rate. The proposed method is comes under model based approach in which the OD is considered the region where the main retinal vessels originate in a vertical direction. The computation time of the localization process is significantly less because it does not used any segmentation method. Fundus photography is a complicated process. Fundus camera is equipped with a low power microscope and is designed to capture the image of the posterior pole of the eye as well as the whole retina.Optic disc extraction or segmentation is performed using segmented reference images called ground truth on which the optic disc is accurately marked by ophthalmologists. The OD processing includes two main steps: localization (detecting the center point of OD) and segmentation (detecting the disc boundary). Given below is a block diagram of the OD segmentation process.

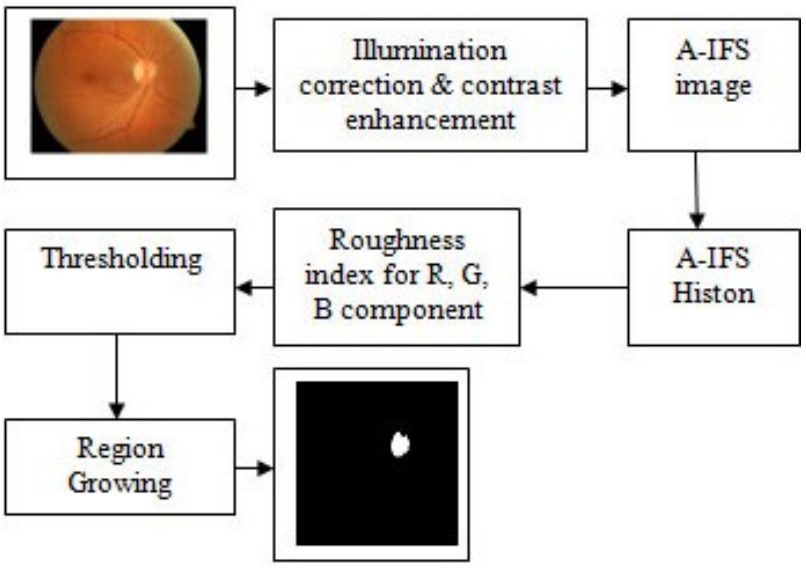

Figure 1: Block diagram of Optic Disk Segmentation Program

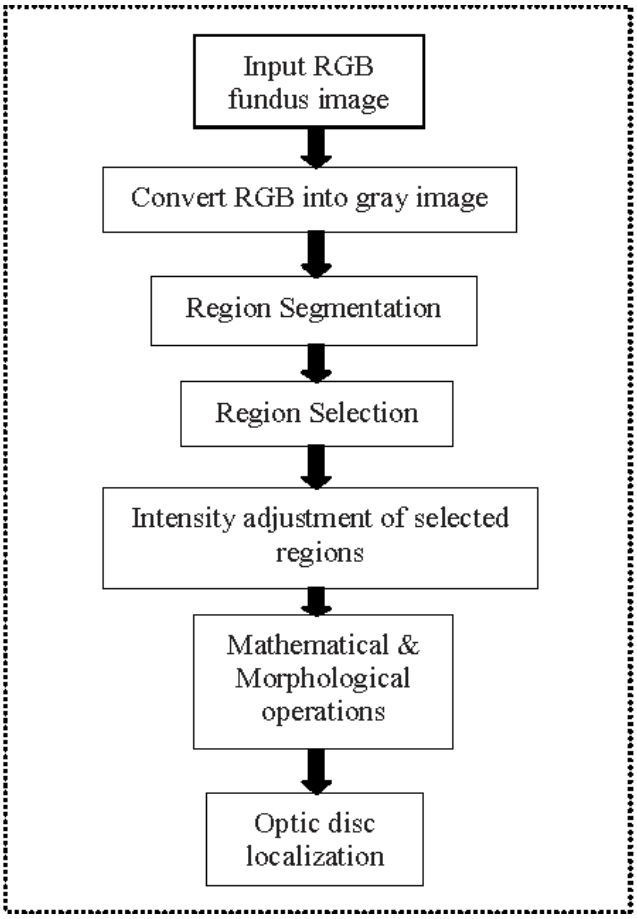

Figure 2: Block diagram of Optic Disk Localization program

A high-level system architecture of retinal image processing showing the data which is employed, the steps which are followed and the procedures which are applied in processing the eye fundus images.

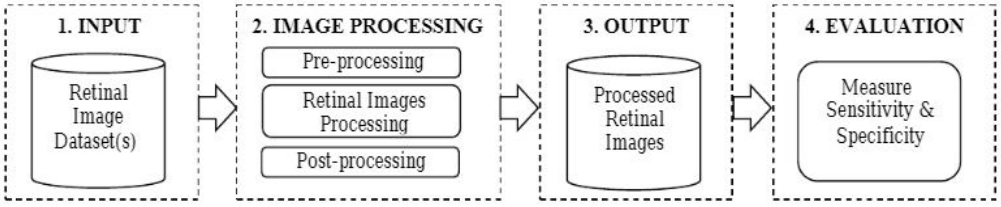

Figure 3: Architecture of retinal image processing method

Each of the four components of the system architecture is briefly described below, and then discussed in detail in the subsequent sections:

- **Input retinal image datasets :** refers to one set or more of retinal images that form the input data to be processed.
- **Image processing :** this is the backbone of the system architecture which is composed usually of three sub-processes in order to manipulate the dataset of the raw retinal images and convert it to a set of meaningful images (e.g. diagnosing a retinal image that suffers from a particular disease):

i. Preprocessing : a preliminary step that normally aims to enhancing the input image (e.g. contrast, sharpness and illumination of the image). ii. Retinal images processing: the main objective of processing the retinal image normally aims to the segmentation of the image which is the process of isolating particular regions of interest within the image. Regions of interest (ROI) may include retinal abnormalities (e.g. exudates, hemorrhages, aneurysms, etc.), and may also include the retinal landmarks (e.g. optic disc, macula, and vascular tree) as discussed earlier. iii. Post-processing: refers to the last processing step that aims to describing and marking (i.e. annotating) either the external boundary or the internal skeleton of the objects/regions that were segmented in the fundus image.

- **Output processed retinal images:** the output dataset which refers to the retinal images after being enhanced, processed and then annotated. These processed retina images are compared to the ground truth in order to evaluate the accuracy of experimental work.

- **Evaluation :** the accuracy of experimental results is measured by estimating indices for the true positive, true negative, false positive, and false negative.

3 Requirement Specifications

3.1 Details of Software

3.1.1 MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include: Math and computation,Algorithm development,modeling,simulation,Data analysis and Application development, including Graphical User Interface building. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar noninteractive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects, which together represent the state-of-the-art in software for matrix computation. MATLAB is widely used in various fields such as data analytics, digital signal processing, image processing, neural networks, deep learning and so on. The advantage of using MATLAB is that it has a wide set of in-built functions which makes it easier to write programs even for complex processes such as digital signal processing and deep learning.

4 System Implementation

4.1 Modular Description of MATLAB Code

The aim of our project is to locate center of the optical disc of the retinal images taken into consideration which has been implemented using MATLAB

Template creation:

This part of the code reads the image from any source and to decrease the effect of noise an average filter with the size of 6 6 pixels is applied to retina image. Then, an 80 80 pixels window is moved through retinal image. To obtain the necessary values from the template we apply the built in function"imfilter". To display the image we use the function imshow().This image of 80x80 pixel is saved as cropped in the template.Matlab code for this step is as shown below.

```
a = imread('2.tif');
h = fspecial('average', 6);
b = imfilter(a, h);
imshow(b)
```

Once the filtering of the image is done we extract the channels of the optical disc i.e red,green and blue channels which is basically the histograms of the color components and save it as count1,count2 and count3,and to extract the histograms we use the built in function imhist().This information is stored in the template data.The code for this step is as shown below.

```
r = cropped(:, : , 1); g = cropped(:, :, 2); b = cropped(:, :, 3);
[counts1,  ] = imhist(r);
[counts2,  ] = imhist(g);
[counts3,  ] = imhist(b);
```

Template Matching:

In the template matching image saved in the template is taken as a reference to locate the center of the optic disc of any given retinal image. In the template matching initally we load the template data into the main program so that we can access all the in-

formation present in the template which is required for the matching the template.Some of the parameters like template size , weights of the colour components are declared initially whose code is written as below.

```
tic
load templateData
templateSize = 80;
tr = 0.5; tg = 2; tb = 1;
```

Now we load the retinal image for which we need to locate the center of the optic disc.Now all the processes done during loading the information into the template data is repeated like reading the image ,applying the average filter on the retinal image and extracting the histograms of the color components and saving it as c1,c2 and c3.It is done by moving a window of 80 x 80 pixel through the retinal image.The code for this process is written as below.

```
a = imread('2.tif');
h = fspecial('average', 6);
b = imfilter(a, h);
imshow(b)
m = 0;
maxValue = 0;
c = zeros(size(b,1)-templateSize+1, size(b,2)-templateSize+1);
for i = 1:size(b,1)-templateSize+1
for j = 1:size(b,2)-templateSize+1
bTemp = b(i:i+templateSize-1, j:j+templateSize-1, :);
red = bTemp(:,:,1); green = bTemp(:,:,2); blue = bTemp(:,:,3);
[c1,  ] = imhist(red);
[c2,  ] = imhist(green);
[c3,  ] = imhist(blue);
```

During template matching we calculate the co relation between the histogram of each channel in the moving window and the histograms of its corresponding channel in template to obtain the similarity between the two histograms. The function used for correlation between two histograms is expressed in the following equation: formula where a and b are the histograms we want to relate and c is the corelation result.C(i,j) represents

corelation for a template.And the matlab code for this step is shown below.

```
sum1 = 0;
for k = 1:200
sum1 = sum1 + (c1(k)-counts1(k))^2;
end
cr = 1/(1+sum1);newline sum2 = 0;
for k = 1:200
sum2 = sum2 + (c2(k)-counts2(k))^2;
end
cg = 1/(1+sum2);
sum3 = 0;
for k = 1:200
sum3 = sum3 + (c3(k)-counts3(k))^2;
end
cb = 1/(1+sum3);
c(i, j) = cr*tr + cg*tg + cb*tb
```

The maximum value of corelation is calculated which is the center of the optic disc of the given retinal image whose code is as shown below.

```
if(c(i, j) > maxValue)
maxValue = c(i,j);
iMax = i;
jMax = j;
```

5 Simulation Output - MATLAB

5.1 MATLAB Output Description

The retina is a most important part in the human eye, which is the important for biometric recognition system, so identifying te retina is a crusial process before implementing any project on iris based recognition system. One of the most unique and new method for localising the centre of the optic disc is by histogram matching. The correlation between the templates and the given retinal image to obtain the histogram, which is matched with different templates to identify the centre of the optic disc. The output of the implementation shows the accuracy of this method for localising the centre of the optic disc. The accuracy of this method can be increased by using another method with pathological regions and exudates exit, as this method of optic disc localisation fails in the template matching algorithm. Also, the time taken for localisation will be reduced for such situations.Therefore, we can use template matching method for retina images to obtain candidate regions that probability of existing optic disc in them is more than other regions in retina images. Then, instead of applying our proposed method on the whole of retina images, by applying it to candidate regions to obtain optic disc center. Therefore, the running time of this method will considerably decrease. In future work, we use optic disc center obtained as the first step for localizing the boundary of optic disc and also we can use the optic disc center for recognition algorithm in our future research for human recognition based on the retinal images.

6 Results

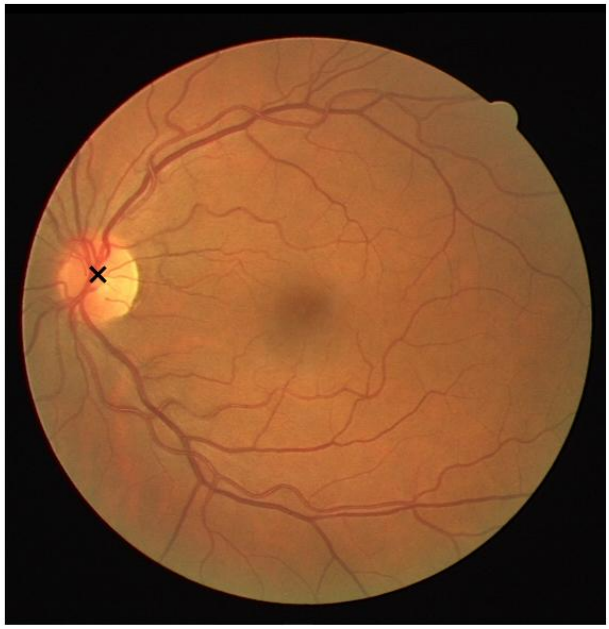

Figure 4: Retinal image with Optic Disk marked - Test image 1

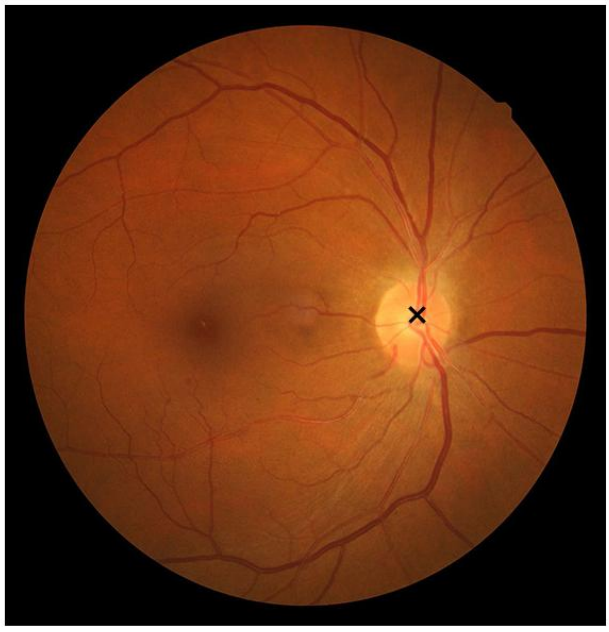

Figure 5: Retinal image with Optic Disk marked - Test image 2

Figure 6: Retinal image with Optic Disk marked - Test image 3

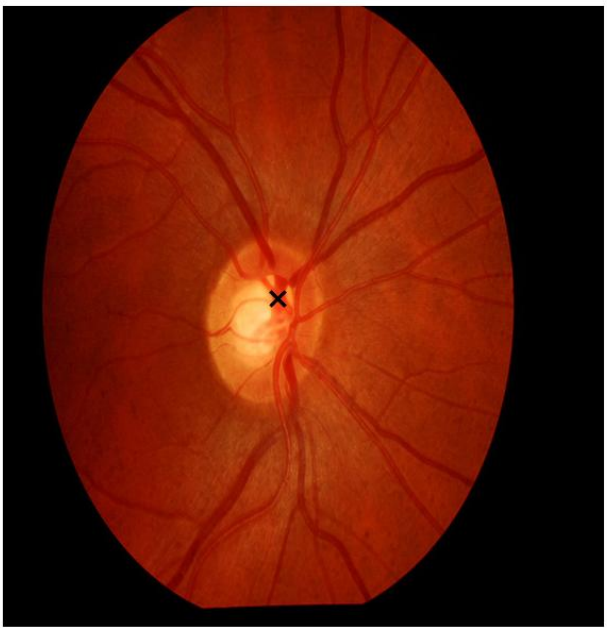

Figure 7: Retinal image with Optic Disk marked - Test image 4

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