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Image Processing Techniques used in Ophthalmology – Detection of Arterial Capillary Vessels in Retinal Images

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Abstract: The significant health issues among the present generation individuals are mostly eye ailments. These ailments can potentially damage eyesight or impair vision. The retina that lines the back of the eye is not only a vital organ of human sight, but also contains valuable data that can be implemented in biometric security applications, or in the diagnosis and treatment of certain maladies. In this paper, we detect the blood vessels present in the retina and also analyze the various ophthalmological ailments such as glaucoma and diabetic retinopathy. Here, we have used RGB image for obtaining the traces of blood vessels. We have proposed a method to detect blood vessels which consists of the following five phases or steps, Pre-processing, Segmentation, Feature extraction, Vesselness Filter and Vessel detection. Moreover, we have also suggested an algorithm for the detection of diseases in fundus images of the retina. The performance of algorithms is compared and analyzed on an average basis, and can be comparable to existing ones.

Keywords Used: Blood vessels, Eye, Filters, Image Processing, Retina, Segmentation

I. INTRODUCTION

The eye is a crucial organ that provides the magic of sight. It allows us to observe, react and adapt to surrounding environments by interpreting shapes, colors and dimensions of objects seen. This is accomplished when the lens present in the eye focuses light onto the photoreceptive cells of the retina. The photons of light trigger a response by producing neural impulses which are, in turn suitably processed by different parts of the brain. The anatomy of the eye can be seen in Fig.1. The external part consists of the sclera and cornea. The intermediate layer is split into two parts: iris and ciliary body. The internal layer is the retinal wall where all the important blood vessels are present.

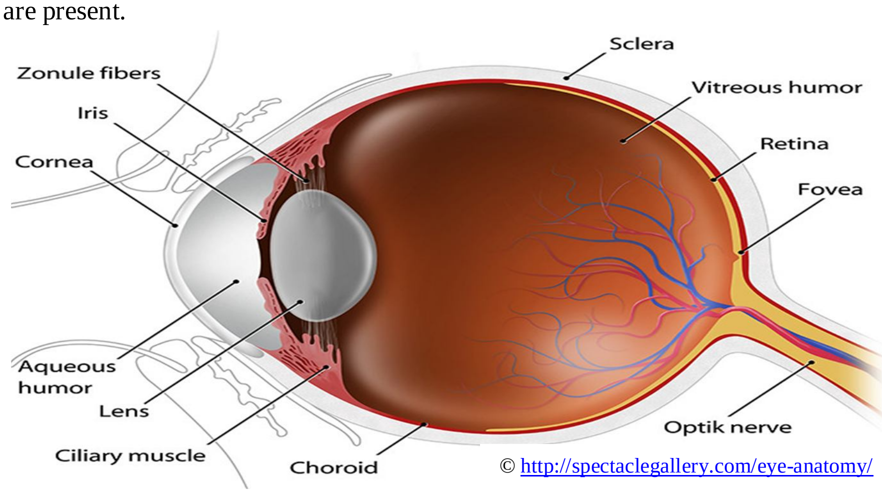

Fig.1: The Human Eye

The cornea is a tough transparent tissue that covers the anterial surface of the eye. Sclera is an opaque membrane that encloses the part of optic globs. It lies directly below the sclera which contains the network of blood vessels. These blood vessels are the major source of nutrients to the eye. Retina is the inner most layer of eye,which, in turn is responsible for visualization of external scenarios. It is a thin layer of tissue in the back of the eye that senses light and sends images to your brain. In the centre of the retina there is the optic disk, exhibiting a circular to oval shape. From the centre of optical nerve radiates the major blood vessels of the retina.

This network of blood vessels is an important biological structure in human retina, which nourishes the cells and nerves present in the vicinity However, manual detection of blood vessels is not that straightforward because these blood vessels are extremely complex to diagnose and have low contrast. Generally, the retinal fundus images, taken from specialised fundus cameras, is widely used in the diagnosis and treatment of various types of diseases such as glaucoma, diabetic retinopathy and more.

A. A Brief Overview

Blood vessels detection is an important but complicated task during surgeries. An unexpected location of a blood vessel or any type of complex anatomical variations may result in an accidental injury to the blood vessel, or can be fatal too. This problem could extend the operation time or cause a serious complication.

Following steps are used for blood vessel detection:

The first and foremost step is the pre-processing of retinal image that is done to improve the quality and characteristics of the retinal images. To further enhance the blood vessels, we have then used vesselness filter in second step. In the final step, classifier filters such as Hessian multiscale enhancement filter is designed from the adaptive thresholding of the output of the vesselness filter for vessels detection.

The proposed method for detection consists of following main steps:

1) *Pre-Processing:* The main objective of pre-processing technique is to attenuate image variation by normalizing the original retinal image.
   a) *Image Resize:* In this step, we change the image size. Resizing will not affect the screen display.
   b) *RGB to HSV Processing:* HSV color model remaps the RGB colours into dimensions that are much easier to understand. By applying the HSV color model, a color is specified then white or black is then added to easily perform color adjustment.
   c) *Filtering:* To reduce the distortion or noise in the image.
2) *Segmentation:* The primary goal behind segmentation is to simplify an image into something that is more meaningful and easier to analyze or understand. Retinal vessel segmentation is an essential step of the diagnosis of various eye ailments. Segmentation is used in compression to compress different areas and various segments of an image, at different compression quality.
3) *Feature Extraction:* Now, once the image is divided by using segmentation, we then extract some specific features in image. Feature Extraction plays a very crucial role in the area of image processing. The main goal of Feature Extraction is to obtain more relevant information in a lower space.In this case, we are determining a subset of the initial features.
4) *Classifier:* In our methodology, we are using the Random Forest classifier,which, in turn, is a flexible, ease to use machine learning algorithm that produces great results most of the time.Random forest, as its name implies, consists of a large number of individual decision trees that operate as an entity. This classifier is basically used for both classification and regression tasks. Another great quality of Random Forest algorithm is that it is very easy to measure the relative importance of each feature on the prediction.

Preprocessing and vessel enhancement:

We know that, based on the Retinex theorem, any given image I can be represented as a component-wise multiplication of its reflectance R and illumination L as: $I = R \times L$.

Let, x = pixel that belongs to image I.

Now, the pixel x of the reflectance image $R(x)$ could be obtained by computing the difference of the logarithms between the original image $I(x)$ and the resulting image $L(x)$ after applying a bilateral filter to the original image $I(x)$, defined as:

$R(x) = \log(I(x) + 1) - \log(L(x) + 1)$

$L(x) = M^{-1}(x)\int_{w} I(\ )g(\ , x)s(\ , x)d\ell$

$M(x) = \int_{w} g(\ , x)s(\ , x)d\ell$

$$g(1, x) = e^{-\frac{1}{2}\left(\frac{d(1,x)}{\sigma_d}\right)^2}$$

$$s(1, x) = e^{-\frac{1}{2}\left(\frac{d(I(1),I(x))}{\sigma_r}\right)^2}$$

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Filter stands for Bar-selective Combination Of Shifted FIlter REsponses. It was proposed by Azzopardi et al. for the detection of patterns with a bar shape. The blood vessels are enhanced with B-COSFIRE filter by using a bank of collinearly aligned Difference of Gaussian (DoG) filters that have been configured accordingly for detecting the bar-like appearance of blood vessels at different angles. A DoG filter for detecting the intensity variations of the image can be defined as:

$$DoG\left(x,y\right)=\frac{1}{2\pi\sigma^2}exp\left(-\frac{x^2+y^2}{2\sigma^2}\right)-\frac{1}{2\pi(0.5\sigma)^2}exp\left(-\frac{x^2+y^2}{2(0.5\sigma)^2}\right)$$

Where σ denotes the standard deviation of the Gaussian function.

II. RESULTS AND DISCUSSION

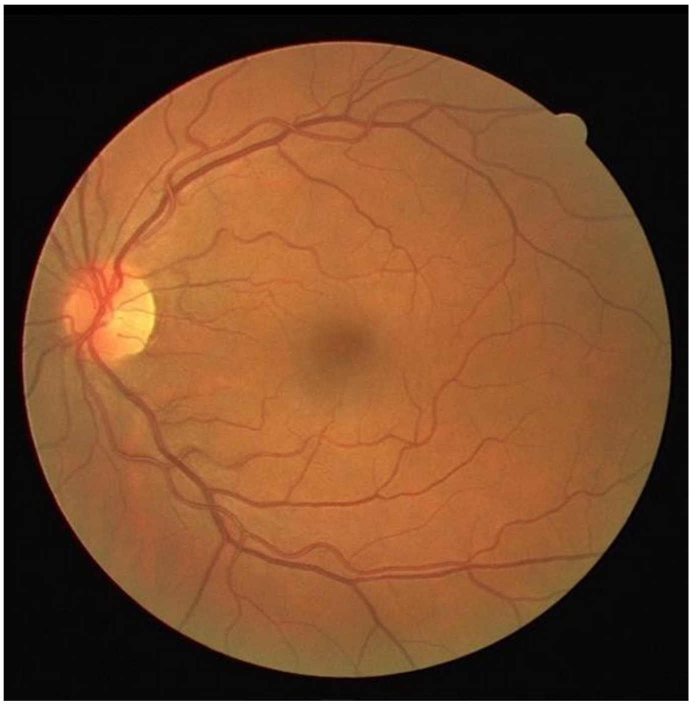

Fig.2: Sample Test image from dataset

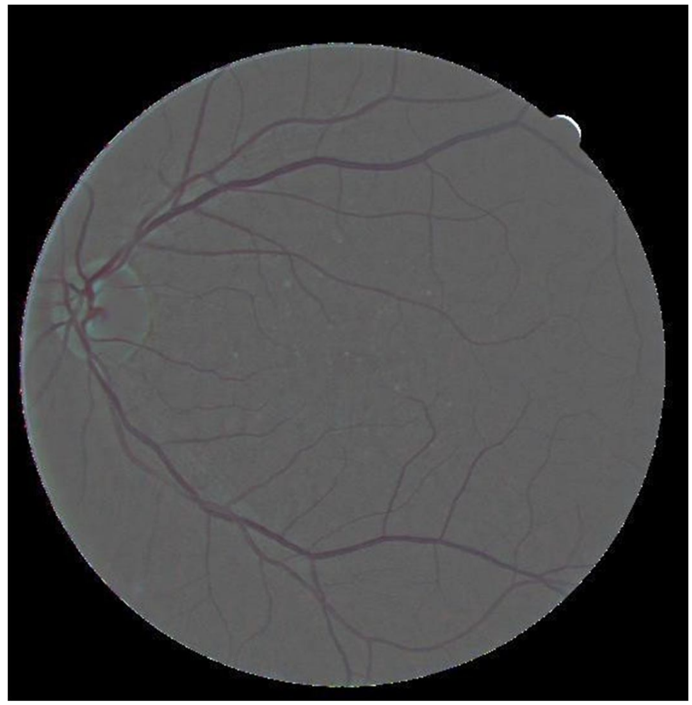

Fig.3: Image with background normalisation

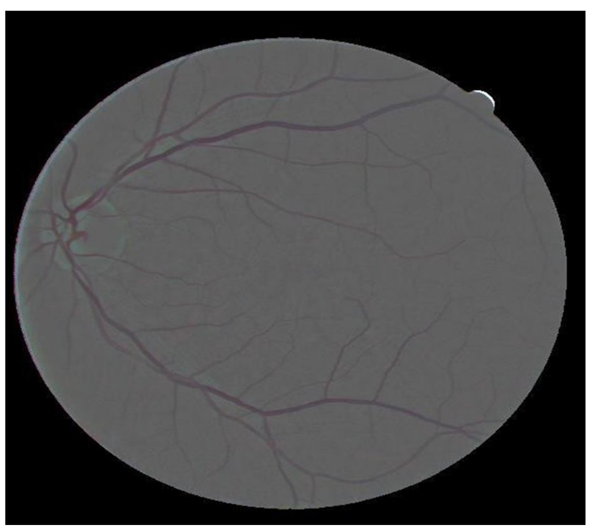

Fig.4: Detail-preserved, noise-removed image

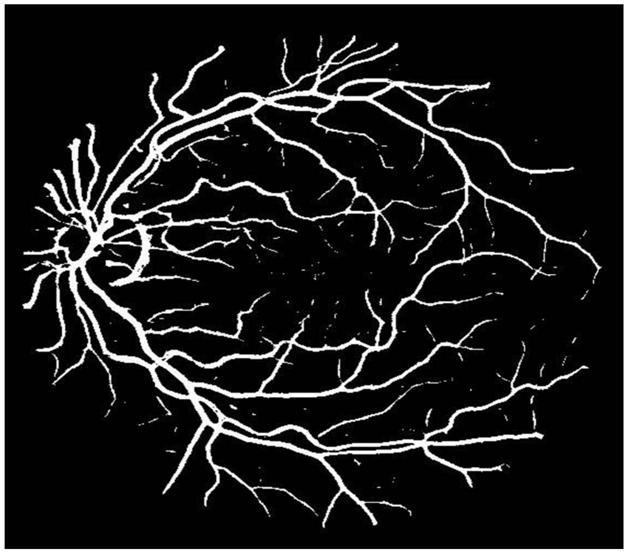

Fig.5: Final pre-processed image after applying filter

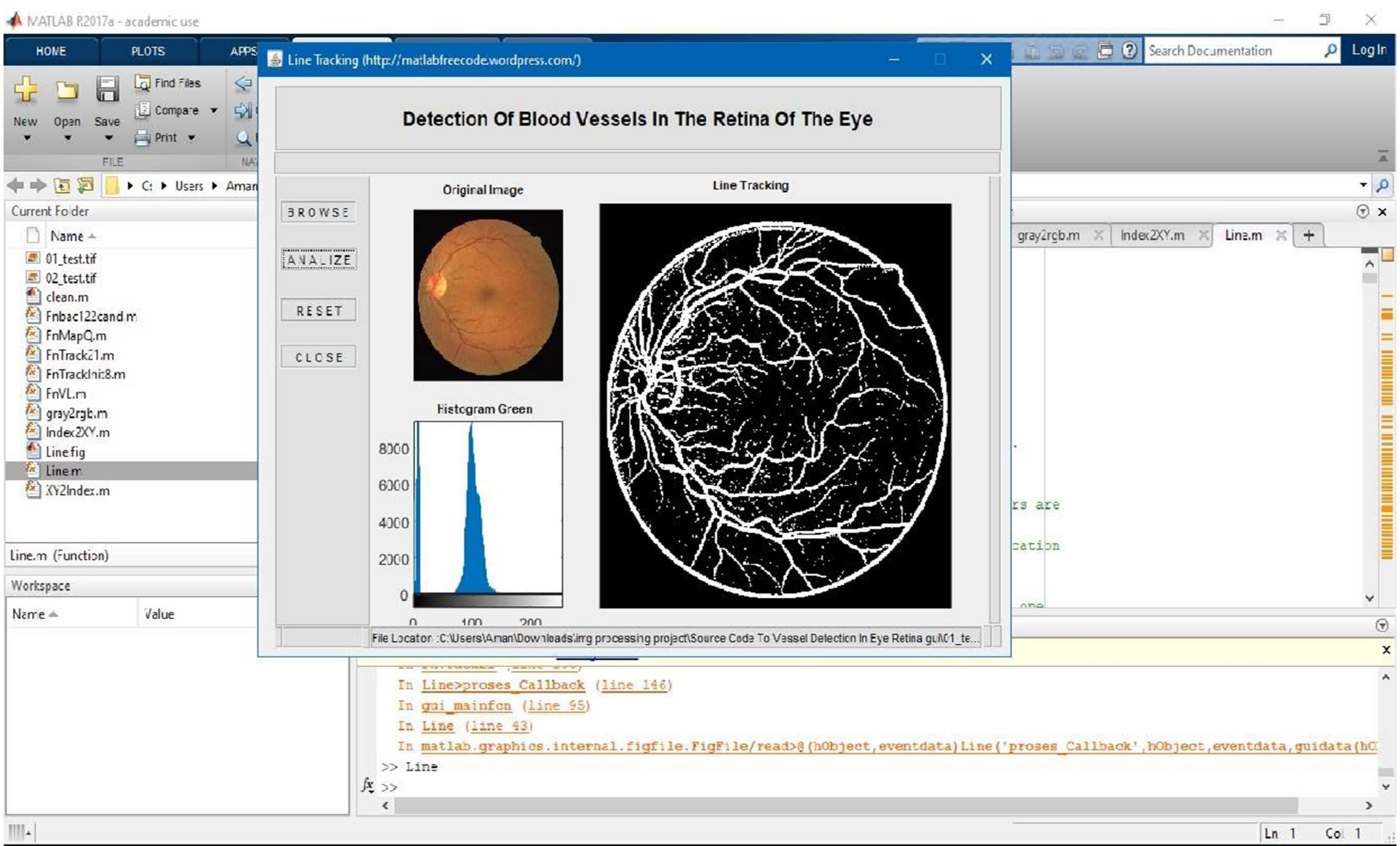

Fig.6: GUI (Graphical User Interface) made in MATLAB

A. Potential Limiting Factors Affecting the Project

It can be observed that the segmentation result is not very accurate. This is most likely caused by using a very small training set (to make testing convenient). It could also be an undetected bug in our code (potentially in the function “matlab:determine_threshold”). Moreover, Matlab's built-in morphological operations produce slightly different results than the paper. This could potentially be an error in choosing our structural element when applying the operations.

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III. CONCLUSIONS

In this article, we have explored the various segmentation methods and techniques used for the detection of numerous eye ailments.It can be considered as an important step towards the existing automated retinal analysis tools. This work could be useful in determining many diseases by applying specific techniques of digital image processing on any given or applicable fundus images. Segmented vessels are routinely used as features in retinal disease classification systems which are,in turn, used for identification of several systematic and lifestyle diseases such as stroke, hypertension or diabetes, to name a few. Moreover, a supervised retinal vessel segmentation algorithm based on matched filters and classifiers is also proposed, which can handle pathological retina images and produces good segmentation, especially in thinner vessels.

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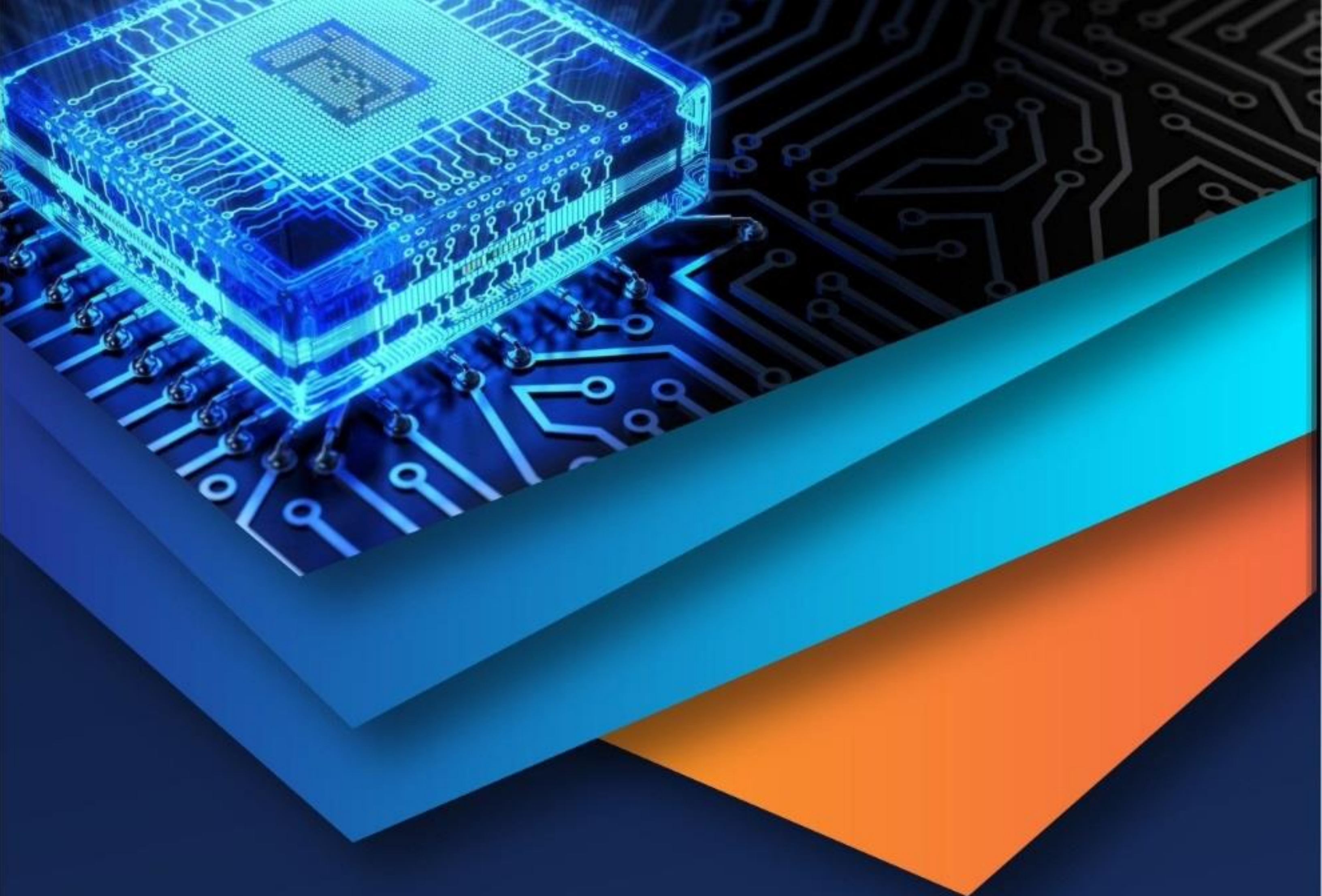

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