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EXTRACTION AND 3D RECONSTRUCTION OF RETINAL BLOOD VESSELS FROM SINGLE FUNDUS IMAGE

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Abstract- 3D modelling has gained lot of importance in the field of medical Image analysis. 3D models give the depth information of the object which is very useful in visualization. The analysis of the blood vessels in the retinal image is helpful for identifying the different diseases such as stages of diabetic retinopathy, glaucoma etc.3D retinal blood vessels would be helpful in explaining to patients about the progression of a disease in the eye and for diagnostic records. This paper presents a simple algorithm to model the 3D structure of blood vessel, which is an extension of the previous work [1]. In this work 3D model of blood vessel is obtained by using gradient method, unsharp masking and shape from shading. Simulation results on a set of retinal images verify the effectiveness of the proposed method.

Keywords— Shape from Shading (SFS), Gradient, Fundus image, 3D reconstruction, unsharp masking

I. INTRODUCTION

Retina is the innermost layer of eye. It is composed of several anatomical structures which can indicate many eye diseases such as glaucoma, diabetic retinopathy etc. One of the major anatomical structures is the blood vessel, which plays an important role for computer assisted retinal image analysis and disease diagnosis. The appearance of blood vessels provides information on pathological changes caused by some diseases. Visualization using the 3D model of the blood vessel will be very useful for the diagnosis of retinal disease, treatment planning and also for educational purpose.

3D visualization technique is suitable for the display of complex structures [1]. The 2D representation has certain disadvantages in terms of lacking in giving different views of the object, information loss due to unavailability of depth information of the object, not providing much information about the structure of the object, and lack of giving realistic effect. These drawbacks can be overcome by developing 3D models that have an additional '*z*' direction which gives the depth information of the object which is very useful in medical image visualization.

The proposed algorithm is fully automatic, less complex and the 3D view is obtained by taking only one view of the fundus image. 3D model of blood vessels in retinal image is simulated using Shape from Shading technique based on Lambertian reflectance and gradient method. The paper is organized as follows: Section 2 gives a survey on the existing literature of 3D reconstruction techniques of retinal blood vessel. In section 3 the implementation of the reconstruction using SFS method has been explained. The experimental results and conclusion are given in sections 4 and 5 respectively.

II. LITERATURE REVIEW

Different work focuses on the 3d reconstruction of fundus pattern [7, 8, and 9]. An approach to 3D reconstruction of blood vessels has been presented by Liu, et al. [10] where a self-calibration based on essential matrix is used.

3D reconstruction of the blood vessels in human retinal fundus image using a sequence of views is presented in Arturo et al paper [6] .This paper presents a methodology for the estimation of the 3D structure of retinal blood vessels from a sequence of fundus images taken from the same subject. In this method self-calibration method is used to find out the camera parameters based on correspondences between images and then the blood vessel skeleton is extracted from the different views .After this matching of the corresponding points of two skeleton structure is performed and triangulation is done. Finally a surface model is generated for 3D visualization.

All methods available require multiple fundus images for processing. Acquiring multiple images may not be always possible on a real time basis. This requires the patients consent and is costlier and time consuming. In this paper, a method for reconstruction of retinal blood vessel from single fundus image using Shape from shading approach based on lambertian reflectance has been used. SFS method is mainly exploited by the artists, the lighting and shading to convey the vivid illusions of depth in paintings.

III. SIMULATION DETAILS

The dataset used for this work consists of Images which are of size 2240 x 1488 and in JPEG format. The images from the DRIVE database were also used for testing the algorithm. This implementation was done using MATLAB version 7.10.0.

A. System Diagram

The proposed algorithm is composed of four steps as shown in Figure 1. Since green channel has the greater distribution throughout the image, green channel is first extracted. Since blood vessels usually have lower reflectance compared with the background, image negative and gradient is applied next to enhance the blood vessel and finally for 3D model, shape from shading is performed.

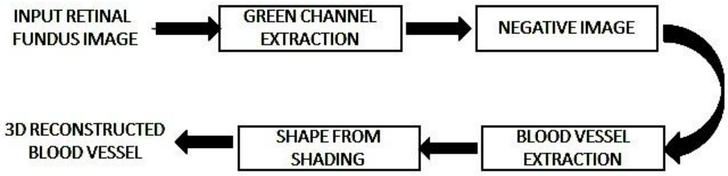

Figure 1: overall system diagram for 3D reconstruction of blood vessel.

Input retinal fundus image are generally color images. From the input color image green channel alone is extracted. After that negative image of the green channel is obtained using negative transformation. Output of the negative image has the enhanced blood vessels. So the blood vessels can be treated as the edges. The gradient of the enhanced image was taken to highlight the blood vessels alone. Finally the gradient image undergoes shape from shading method to obtain the 3D model of blood vessel.

B. Green Channel Extraction

Retinal fundus images are color images. It consists of three channels red, green and blue. Out of these three channels here green channel is extracted in order to reduce the computational complexity. Also from the literature review it is found that the green plane was used in the algorithms due to the greater distribution of intensity through the image.

C. Image Negative

Optic disk is the brightest region in the fundus image.To make this region as dark and to enhance the blood vessels negative of the green channel is taken.The idea of image negative is to reverse the order from white to balck and viceversa so that the intensity of the output image decreases as the intensity of input increases.
Image negative is obtained by the relation

$$N(x,y)=L-1-r \text{----------(1)}$$

Where 'r' is the input pixel value and L is the number of gray levels of the input image.

D. Blood Vessel Extraction

In this method blood vessel enhancement is performed by using gradient method and unsharp masking method.
Image differentiation enhances edges and other discontinuities and deemphasizes areas with slowly varying gray level values.The *gradient* of an image is defined as

$$\nabla F = \frac{\partial F}{\partial x}x + \frac{\partial F}{\partial y}\text{-y--------- (2)}$$

which is a first derivative operator. This can be considered as a high pass filter which can provide more visible details that are obscured and of poor focus in the original image. The unsharp filter is a simple sharpening operator which enhances edges and other high frequency components in an image. It is obtained by subtracting an unsharp, or smoothed, version of an image from the original image.

$$g(x,y) = f(x,y) - fsmooth(x,y) \text{--------(3)}$$

The advantage of using Unsharp Mask filter is it sharpens edges of the elements without increasing noise.

E. Shape From Shading

From the reflectance and illumination nature of an image, by examining the shading information, generating a 3D visible image from a 2D image is known as a Shape from Shading method.SFS computes the depth from a single shaded image. In this work shape from shading using linear approximation is used,which is a local method and it is based on Lambertian reflectance.

This work has been done based on the assumption that the fundus images exhibit the property of lambertian reflectance. For the simulation TSAI and SHAH algorithm is selected and the algorithm is explained in [1],[5].

IV. RESULTS AND DISCUSSIONS

Figure 2 shows the original fundus colour image. Figure 3,4and 5 gives the red, green and blue channels of retinal fundus image respectively. Experimental results reveal that green channel has the clear picture of the blood vessels. Hence this channel is used for further processing. The negative of the green channel is shown in Figure 6. The pixel intensities are reverted in the negative image. Figure 7 and 8 shows the blood vessel extracted using the gradient method and unsharp method. Figure 9 and 10 gives the 3D model of the blood vessels in the retina by the two methods from the 3d obtained by unsharp masking method is better than gradient method . The 3D output can be rotated at any angle to get a 360 degree view of the retinal blood vessels.

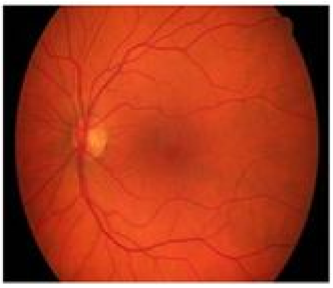

Fig. 2 An original retinal image

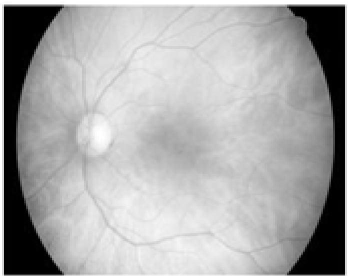

Fig. 3 Red channel of original image

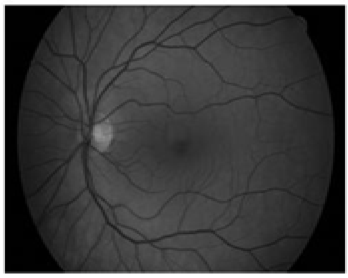

Fig. 4 Green channel of original image

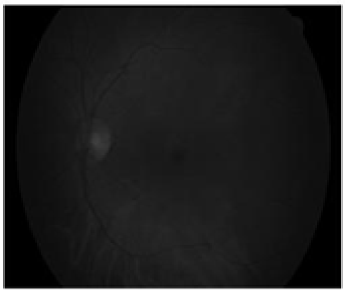

Fig. 5 Blue channel of original image

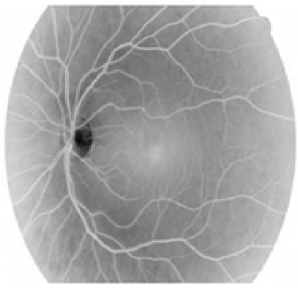

Fig. 6 Negative of the green channel

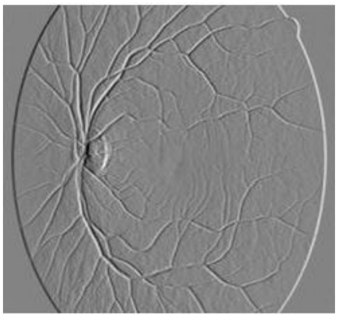

Fig. 7 Blood vessel extraction using gradient

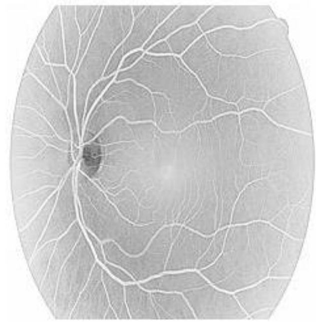

Fig. 8 Blood vessel extraction using unsharp masking

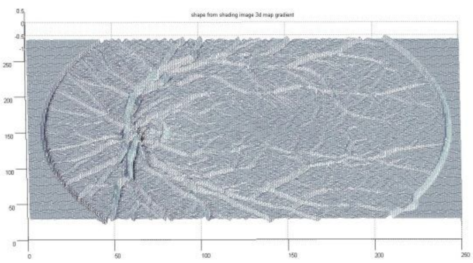

Fig. 9 3D model of blood vessels using gradient

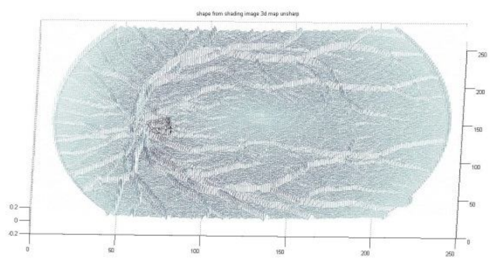

Fig. 10 3D model of blood vessels using unsharp masking

V. Conclusions

In this paper a simple method for 3D reconstruction of retinal blood vessels from single fundus image using shape from shading method has been proposed. Constructed 3D model is used for visualizing images of various retinal diseases. The SFS method used here is based on intensity or spatial domain instead of Fourier domain and it is computationally simple. This method has less complexity and is fully automatic. An important feature of the method is that the 3D is obtained by using only single view of the image compared to the previous methods. The obtained model can also be rotated for better analysis.

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