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Color Retinal Image Enhancement And Segmentation For Effective Detection Of Defects In Blood Vessels

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***Abstract*— Among the many uses of retinal images are in the early detection and diagnosis of many eye diseases such as diabetic retinopathy (DR) and age-related macular degeneration (AMD). Retinal images are acquired with a digital fundus camera, which captures the illumination reflected from the retinal surface. Despite the controlled conditions under which imaging takes place, there are many patient-dependent aspects which are difficult to control. Some of the contributing factors are: (a) The curved surface of the retina. Consequently, all retinal regions can not be illuminated uniformly;(b) Imaging requires a dilated pupil. Dilation is highly variable across patients; (c) Unexpected movements of the patients eye. The bright flash – light makes the patient move his/her eye away from the view of the camera involuntarily; (d) Presence of other diseases such as cataract which can block the light reaching the retina. These factors result in images having a large luminosity and contrast variability within and across images. Hence, for a reliable diagnosis, whether manualor automated, an image normalization step is necessary. These existing methods can broadly be divided into three types: histogram based, filter based, and transformation based. Most of these methods focus on enhancing retinal blood vessels to achieve better vessel segmentation through increasing the contrast between blood vessels and the retinal background in both grayscale and color retinal images. The above methods do not behave well with color retinal images Thus the enhanced image of retina can lose the colour information or other important features including optic disc, macula lutea, and various lesions. In order to preserve the information in the images, and to obtain more details from the image without colour distortion and over-enhancement, we present a novel technique of image fusion. In image fusion technique will combine relevant information from two or more images into a single image. The resulting image will be more informative than any of the input images. This method of color retinal image enhancement using image fusion technique may be employed to assist ophthalmologists in more efficient screening of retinal diseases and in development of improved automated image analysis for clinical diagnosis.**

***Index Terms*— Luminance, contrast, enhancement, CLAHE, gamma correction, fundus image.**

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I. INTRODUCTION

To study the effects of retinopathies and other systemic diseases on the retina and its vasculature, one needs to understand the detailed architecture of retina and ocular structures. The schematic shows different ocular structures and retina which is positioned on the back side of the eye, covering it from inside. Retinal membrane consists of nerve cells which are sensitive to light and are classified into two types, viz., rods and cones. The nerve cells are the mediators between optical signals received at the retina, and part of the central nervous system dealing with the visual senses. Rod cells are responsible for black and white vision, the peripheral vision and the vision in dim lighting conditions, whereas the cone cells deal with both black/white and the color vision. Cones are present in the ocular structure known as fovea, which develops the high visual acuity in the central vision.

The retinal vasculature (Fig. 1.1(b)) and the neuronal network organized on the retina are responsible for blood circulation in the inner retina and nervous system signal transmission, respectively. Development of a vasculature on the retina is dependent upon the growth of ocular structures and nervous system during the embryonic stage, along with the oxygen requirements and presence of vasoactive growth factors such as VEGF.

The retinopathies or the diseases may affect the retina through the abnormal blood circulation in the vasculature. These diseases are mainly classified into two types: Retinal abnormalities which may be accounted as ischemic diseases, vessel occlusions, hemodynamic diseases, retinal stresses, radiation damages and inammation. The other type is regarded as the causes of abnormal blood circulation produced in the retina due to the systemic dysfunctions. Metabolic behaviors which get affected through diseases such as diabetes, hypertension, cardiovascular diseases, cancers and blood infections, produce detrimental effects on the entire system including the retina and its circulation.

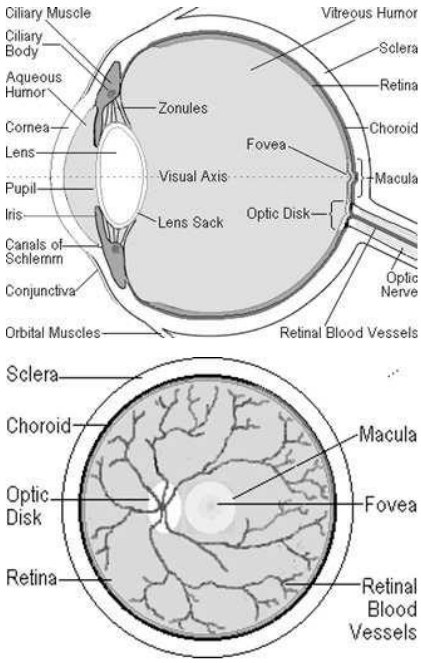


Figure 1.1 The Eye a) Side View, b) Rear View

II. Literature Survey

In this chapter we seek to describe and discuss the development of this project based on researches that have been carried out previously and recorded in journals, articles and also textbooks. Biometrics comes from the Greek language and is derived from two words bio (life) and metric (to measure). It is used to attain various characteristics of human that could distinctly identify them from each other. These characteristics can uniquely identify a person and thus used to replace traditional methods of security. Personal biometrics cannot be easily stolen and an individual does not need to remember passwords or codes. This helps in solving access control problems, fraud and theft in highly sensitive areas of application and secures facilities.

The retina is a thin layer of cells at the back of the eyeball of vertebrates. It is the part of the eye which converts light into nervous signals. The retina contains photoreceptor cells called rods and cones. They receive the light and convert it to electrical pulses which are carried to the brain via the optical nerves present in the retina. The rod system is usually of low spatial resolution but extremely sensitive to light while the cone system is of high spatial resolution but is relatively insensitive to light. The cones are responsible for enabling us to see colors while the rods are responsible for facilitating night vision and peripheral vision.

III. Proposed Method

Generally two types of vision are classified. They are human vision and computer vision. Human vision is sophisticated system that senses and acts on visual stimuli. It has evolved for millions of years, primarily for defense or survival. Basic computer vision system requires a camera, a camera interface and a computer.

A feature closely related to image quality is focus. Sharp images provide better information than blurry images. However, in some situations it is not possible to obtain totally focused images in just one single camera shot, since some regions appear to be blurred due to variations in the depth of the scene and of the camera lenses focus. This means that if the camera is focused at one specific object, another region of the scene can be out of focus. An interesting solution is to take more pictures of the desired landscape in the same position, but with focus centered in different elements of the scenery. Then, using the image fusion concept, all source images are combined, creating a single image that contains all the best focused regions. Image fusion is becoming very popular in digital image processing.

The main aim of any image fusion algorithm is to coalesce all the important visual information from multiple input images such that the resultant image contains more accurate and complete information than the individual source images, without introducing any artifacts.

In general, fusion techniques can be classified into different levels. They are signal level, pixel/data level, feature level and decision level.

Signal level fusion In signal based fusion, signals from different sensors are combined to create a new signal with a better signal to noise ratio than the originals signals.

Pixel/ Data level fusion is the combination of raw data from multiple sources into single resolution data, which are expected to be more informative and synthetic than either of the input data or reveal the changes between data sets acquired at different times.

Feature level fusion extracts various features, e.g. edges, corners, lines, texture parameters etc., from different data sources and then combines them into one or more feature maps that may be used instead of the original data for further processing. It used as input to preprocessing for image segmentation or change detection.

Decision level fusion combines the result from multiple algorithms to yield a final fused decision. When the results from different algorithms are expressed as confidences rather than decisions, it is called soft fusion. Otherwise it is called hard fusion. Methods of decision fusion include voting methods, statistical methods and fuzzy logic based methods.

Because insufficient or uneven luminance obscures visual perception of retinal images, making diagnostic details undetectable, it is essential to enhance the luminance effect first. However, for a color image, the color should not change for any pixel, to prevent image distortion. In general, color retinal images are stored and viewed using RGB color space. The R, G, and B channels simultaneously contain the luminosity information and the color information, which are correlated with each other. To enhance the luminosity and preserve the color, the R, G, and B channels should be adjusted by the same proportion [20]. Our solution is to obtain a luminance gain matrix $G(x, y)$ which is defined as follow:

$$\frac{r'(x,y)}{r(x,y)} = \frac{g'(x,y)}{g(x,y)} = \frac{b'(x,y)}{b(x,y)} = G(x,y)$$

wherer'(x, y), $g'(x, y)$, and $b'(x, y)$ are the enhanced R, G, and B values in the pixel at (x, y) position, and the $r(x, y)$, $g(x, y)$, and $b(x, y)$ are the original R, G, and B values.

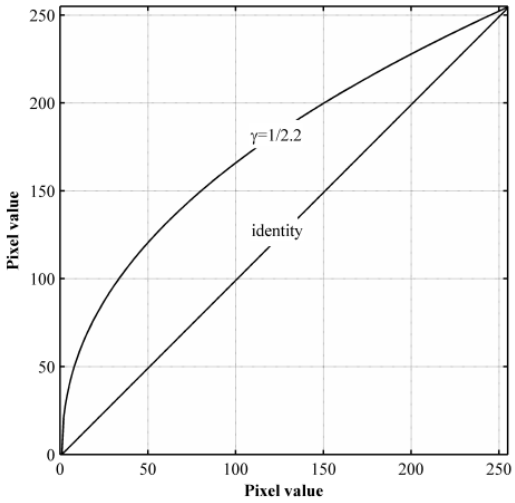


Figure 5.3.Transformation curve of gamma correction and the identity line.

To obtain the color-invariant luminance gain matrix, the color image is transformed into the HSV color space where the luminosity channel (V) is decoupled from the two color components, hue (H) and saturation (S). The H and S channels are irrelevant to luminance, and both are ignored. The luminance intensity of a pixel at the (x, y) position is obtained as the maximum (max) of the R, G, and B values. Therefore, the luminance gain matrix can be inferred as

$$G(x,y)=\frac{V'(x,y)}{V(x,y)}=\frac{V'(x,y)}{\max(r(x,y),g(x,y),b(x,y))}$$

where$V(x, y)$ is the luminance intensity of a pixel at (x, y) position, and $V'(x, y)$ is the function of $V(x, y)$, which determines the effect of luminosity enhancement. We can see that the processing can be directly done in the RGB color space, which reduces the computational complexity.

For the $V'(x, y)$, we aim to significantly increase the dynamic range of the low gray level region, to slightly increase the moderate gray level region, and to maintain or compress the high gray level region. Gamma correction [21], [22], a popular imaging processing methods, is used to transform luminance nonlinearly. The transformation curve is expressed by

$$w=u^{\gamma}$$

where denotes the normalized pixel value of the luminosity channel, w is the normalized output, and γ is a constant. The transformation has a simple pointwise operation form. Before undergoing the transformation, $V(x, y)$ is normalized as the input u. $V'(x, y)$ is the reversed normalization of the output w.

The gamma, γ, is typically greater than 1.0 in a display device,and the standard of the National Television System Committee recommends a gamma of 2.2, which can be used to effectively recover an overexposed region. Whereas $\gamma < 1$ has exactly the opposite effect, the usual setting is 1/2.2, which is also used in our method. The transformation curve of gamma correction is shown in Fig. 5.3. Compared with the identity line when $\gamma = 1$, the nonlinearity transformation can effectively enhance the luminosity. The values in the calculated luminance gain matrix $G(x, y)$ are always greater than or equal to 1. The gray level interval [0, 50] in the luminosity channel (V) is transformed to [0, 122], [100, 150] is transformed to [167, 200], and [200, 255] is transformed to [228, 255]. The transformation can increase the dynamic range of the low gray level and compress the high gray level, which can clarify the details of the retinal image.

Even more importantly, the luminosity enhancement in the HSV color space can effectively take care of the gamut problem [23]. Because the pixel value in the luminosity channel (V) is the maximum value in the R, G, and B channels and the gamma correction does not change the gray level range. The enhanced values $r'(x, y)$, $g'(x, y)$, and $b'(x, y)$ by multiplying the original R, G, and B values and $G(x, y)$ respectively cannot go out of bounds.

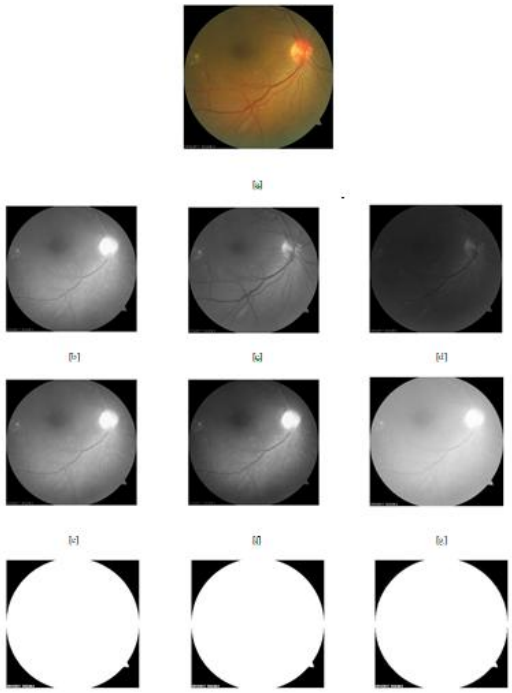
IV. MATLAB CODINGS

```
clc
close all
clear all
%%%%% insert images %%%%%
imsrc = imread('C3.jpg');
figure('name','image source');
imshow(imsrc);
%%%% RGB Extraction %%%%
Rcom=imsrc(:,:,1);
Gcom=imsrc(:,:,2);
Bcom=imsrc(:,:,3);
figure('name','R component');
imshow(Rcom);
figure('name','G component');
imshow(Gcom);
figure('name','B component');
imshow(Bcom);
%%%% Gamma Correction - HSV %%%%%%
imHSV=rgb2hsv(imsrc);
figure('name','value');
imshow(imHSV(:,:,3));
Gama =
imadjust(imHSV(:,:,3),[],[],1.4545);
figure('name','gamma correction');
imshow(Gama);
Gmat=Gama./imHSV(:,:,3);
figure('name','G matrix');
imshow(Gmat);
Rcom=double(Rcom);
Gcom=double(Gcom);
Bcom=double(Bcom);
Rdash=Rcom.*Gmat;
Gdash=Gcom.*Gmat;
Bdash=Bcom.*Gmat;
figure('name','R dash component');
imshow(Rdash);
figure('name','G dash component');
imshow(Gdash);
figure('name','B dash component');
imshow(Bdash);
Imgcomb=imsrc;
Imgcomb(:,:,1)=Rdash;
Imgcomb(:,:,2)=Gdash;
Imgcomb(:,:,3)=Bdash;
figure('name','Luminance Enhanced
image');
imshow(Imgcomb);
```

```
%%%%%%%%%%CLACHE Algorithm%%%%%%%%%
RGB=Imgcomb;
cform2lab=makecform('srgb2lab');
LAB=applycform(RGB,cform2lab);
L=LAB(:,:,1);
LAB(:,:,1)=adapthisteq(L,'clipLimit',0.0
2,'Distribution','rayleigh');
cform2srgb=makecform('lab2srgb');
J=applycform(LAB,cform2srgb);
figure();
imshowpair(RGB, J, 'montage');
title('CLACHE Image');
```

V. OUTPUTS

A typical Retinal Fundus Image is considered (Figure 6.1[a]), and process it through the proposed algorithm and see the results at each stage of processing.



. Figure 6.1:Processing stages for input Image [a] Input Image, [b] R Component Image, [c] B Component Image, [d] G Component Image, [e] HSV Image, [f] Gamma Corrected Image, [g] G Matrix Image, [h] R Dash Component Image, [i] B Dash Component Image, [j] G Dash Component Image.

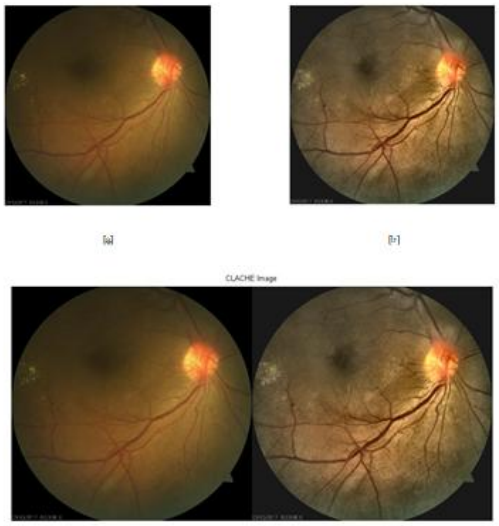


Figure 6.2: [a] Luminance Enhanced Image, [b] Contrast Enhanced Image using CLAHE, [c] Input Output Comparison.

VI. CONCLUSION

Here we present an effective method for color retinal image enhancement based on luminosity and contrast adjustment. First, the luminosity of the color retinal image is enhanced by a luminance gain matrix based on gamma correction, and then image contrast is enhanced by CLAHE in the L*a*b* color space. The performance of our proposed method was validated on two large color retinal image datasets. The results show that, compared with contrast enhancement in other color spaces and other methods, our proposed method achieves superior improvement of color retinal images, especially for those with initially of poor quality. This method is not only able to enhance important anatomical structures of the retina, but it also preserves the naturalness of the images. This effective method of color retinal image enhancement will greatly assist ophthalmologists in disease diagnosis through retinal image analysis, and will be greatly beneficial to automated image analysis systems. The clinical evaluation of our method is currently in progress.

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