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Retinal Image Enhancement by using Adapted Histogram Equalization based on Segmentation and Lab Color Space

Emtinan Mohammed Jawad[1] **Hazim G. Daway[1]*** **Haidar J. Mohamad[1]**

[1] *Department of physics, College of Education, Mustansiriyah University, Baghdad, Iraq*
* Corresponding author's Email: hazimdo@uomustansiriyah.edu.iq

Abstract: Enhancing retinal images is the most important thing to detect eye diseases. Many of the retinal images taken with the optical coherence tomography (OCT) device suffer from uniform lighting and low contrast. In this study, a new method was suggested to enhance retinal images. The suggested algorithm is that the retinal region is segmented, and then the extracted region is improved depending on the (Lab) color space where the lighting component is enhanced using adapted histogram equalization and while preserving the color components (a and b). To see the quality improvement, the quality assessment as peak signal to noise ratio, contrast enhancement measurement, and entropy have been calculated By comparing the proposed method with several other methods as principal component analysis using reflection model (PCAURM), modified color histogram equalization (MCHE), luminosity and contrast adjustment (LCA), fuzzy logic by stretch membership function (FLSMF), contrast limited adaptive histogram equalization (CLAHE) and contrast enhancement approach (CEA) by using driver rental images dataset from the results, it is found that the suggested algorithm has succeeded in enhancing the retinal images and it has the best quality standards rates of PSNR (24.4281), entropy (5.6338) and CEM (0.5746).

Keywords: Adapted histogram equalization, Driver rental images, (LAB) color space, Retinal image enhancement.

1. Introduction

Enhancement images are one of the most important topics in image processing because they are involved in several areas such as medical imagery, object detection [1, 2], surveillance and underwater imagery [2, 4], the important areas in digital image processing are image improvement and retrieval [5, 6], which is applied in several areas including improving aerial images [7], multimedia [8], and medical images [9]. Medical images often need to be improved due to lack of contrast, irregular lighting, or low levels of intensity captured, as in X-ray images. There is a many research that improves images as in images (OCT), most of the existing optimization techniques are histogram equalization and contrast limited adaptive histogram equalization (CLAHE) [10]. In many fields, histogram techniques are used as an important basis in improving medical images. Agung W. Setiawan et al [11] suggested a method to enhance the image and reduce the noise in the retina image by the acquisition process. This method is proposed by using CLAHE in channel G to improve the image quality in the retinal, if there is some distortion in the medical image of the retina, it will affect the quality of the image and it will be a poor quality image. Haoning Lin and Zhenwei Shi [12] introduced a method of night image enhancement method using Retinex method which is usually used on non-uniform images of light and color. Its results are good in terms of chromatic stability and dynamic range compression. The method is multi-scale Retinex (MSR) in low areas. It is sensitive to noise and in areas with normal lighting or intense its results are not good and it leads to a loss of data for night images. In addition to that. It uses the gain compensation method for treatment before display and to reduce data loss in MSR the logarithm function was replaced by the x-ray function assigned to reduce the loss. Mei Zhou,2017 [13] introduced a method based on LCA to enhance the retinal images, this methods focus on enhancing retinal vasculature by increasing the contrast between them and the retinal background in color and grayscale retinal images, the image is of poor quality and is not useful in diagnosis due to the difference in lighting, noise, and contrast in the image, so this image enhancement method is proposed to improve the contrast and brightness in the color retinal image. The lightness gain matrix, by gamma correction of the value channel in the HSV color space (hue, saturation, and value), is used to optimize the R, G, and B (red, green, and blue) channels, respectively. The results of this method are of the best importance in the detection and diagnosis of eye diseases for more effective screening, as well as in the development of automated optimized images for clinical diagnosis. Zimmerman, J. B, et al [14] proposed methods based on the classical histogram were used to improve the fundus image, such as, (HE) and this is the famous classical method that converts gray levels according to cumulative distribution and histogram function of the input image, which is an ineffective method. The CLACH method has been adopted and is more convenient in improving fundus image and noise suppression. J. Wang, et al [15] proposed a method to improve the fundus image. They analyzed the image and divided it into three layers: base layers, detail, and noise. Then, lighting correction, detail improvement, and noise reduction are performed successively in these three layers - specifically, simple optical adaptation.

A. W. Setiawan, et al [11] suggested a chromatic enhancement of the retinal image using CLAHE, retinal image obtained in this study for the fundus camera method available in the ophthalmology hospital or eye examination clinics. This method is considered a standard imaging method. The quality of each image depends on the acquisition process, such as movement, eye blinking, and lighting. As color and contrast are among the important characteristics that are taken in diagnosing the pathological condition of the retina, they are very important for the examiner of the retina, meaning that the noise is caused by varying lights. To reduce the noise, we improve it in this way. More contrast than the background, the intensity value of the image is represented by image histogram. The histogram is to give statistical information from the image. Therefore, the graph file is processed for enhancement. The enhancement process is performed in the three channels in the image.

Hazim G. Daway, et al. [16] suggested using an algorithm to enhance medical images as microscopic, magnetic resonance, and x-ray images depending on FLSMF, this function depending on sigma-mean of the red, green, and blue components. This method succeeded in improving the lightness and contrast of the different types of medical images. Neha Singh and Ashish Kumar Bhandari [17] proposed a method depending on PCAURM. The algorithm proposed in this article works adaptively for dark images by adopting the multiband principle and reflection model. This method yields better results in the context of objective and subjective assessments. Bhupendra Gupta and Tarun Kumar Agarwal [18] suggested a CEA for low lightness image enhancement, in this method YCbCr is treated, and using the YCbCr color model the luminance portion "Y" can be used separately followed by the step of using the newly developed sigmoid function in which the luminance portion "Y" of the image is enhanced.

Wei-Yen Hsu and Ching-Yao Chou [19] suggested an algorithm for image enhancement by preserving hue to address this problem by MCHE. The results showed, by comparing an equal image for each RGB color channel using the traditional method, that the traditional method HE does not preserve the color gradation, the results of the proposed method are superior, with high accuracy of the peak signal-to-noise ratio and average square error. The study was carried out on retina and cancer images.

In this study, the aim was to improve retinal image, based on the CLAHE technique, which is applied only to the retinal area by deducting it with the use Lab color space.

2. Suggested method

The effectiveness of optimization can be increased by segmenting [20], when enhancing with segmenting techniques for the entire image (consisting of the retinal and black background) the enhancement image turns to gray, we prefer to isolate this region upon enhancement.

2.1 Segmentation of retina region

The proposed isolation technique is based on converting the image to binary. The retinal area is thus isolated based on morphological processes, the gray or lightness value at position u and v being calculated first by:

$$I(u,v) = \max\left(\mathrm{r(u,v)}, \mathrm{g(u,v)}, \mathrm{b(u,v)}\right) \quad (1)$$

And then convert the lighting channels to the binary system according to the condition:

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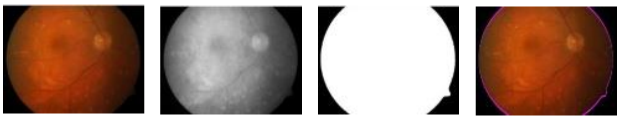

(a) (b) (c) (d)

Figure. 1 The stages of isolating the retinal area and converting it to the binary system: (a) original, (b) gray, (c) binary, and (d) retina

$$\left.\begin{array}{c}\text{if } \mathrm{I(u,v) > th} \\ \mathrm{Ib(u,v) = 1} \\ \text{else } \mathrm{Ib(u,v) = 0}\end{array}\right\} \tag{2}$$

After this, the average filter is used with window size (5×5) in order to fill in the small gaps and delete small areas. This process is considered a final process to detect the area where the white image is, so it is necessary to project the coordinates of the white area onto the original retina image and according to the condition. In this study we use $(th = 0.01)$.

After isolating the white area (n), the coordinates are projected onto the original image in order to isolate it according to the following relationship:

$$\left.\begin{array}{c} for\ all\ c(u,v,i), i = 1{,}23 \\ If\ Ib\ (u,v) = 1\ then\ m = v, n = u\ , \\ save\ C_{crop}(n,m,i)\end{array}\right\} \tag{3}$$

Where $c_{crop}(n,m,i)$ the retinal color image is will be enhanced with i=1,2 &3 are red, green and blue (r', g'. and b') Fig. 1 illustrated the stages of isolating the retinal area.

2.2 Enhancement lightness component-based color space

The lightness component is only improved in isolation from the chromatic components based on the Lab space. This method of enhancement allows for increasing the lightness without causing distortions in the original colors. The CLAHE method will be adopted to improve the lighting component. The image is converted from RGB space to Lab space according to the following equations [21]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.41 & 0.35 & 0.18 \\ 0.21 & 0.71 & 0.07 \\ 0.01 & 0.11 & 0.95 \end{bmatrix} . \begin{bmatrix} r'(x,y) \\ g'(x,y) \\ b'(x,y) \end{bmatrix} \tag{4}$$

$$\mathrm{f}(r) = \begin{cases} \sqrt[3]{r} & for\ r > e, \\ 7.787r + \frac{16}{116} & for\ \leq e. \end{cases} \tag{5}$$

$$L = \begin{cases} 116 \left(\frac{Y}{Y^n}\right)^{\frac{1}{3}} - 16 & \frac{Y}{Y^n} > e \\ 903.3 \left(\frac{Y}{Y^n}\right) & \frac{Y}{Y^n} \leq e \end{cases} \tag{6}$$

$$a^* = 500 \left(f\ \left(\frac{X}{X^n}\right) - f\ \left(\frac{Y}{Y^n}\right) \right) \tag{7}$$

$$b^* = 200 \left(f\ \left(\frac{Y}{Y^n}\right) - f\ \left(\frac{Z}{Z^n}\right) \right) \tag{8}$$

($e = 0.008856$), It is preferable that the values of L are stretched (0,1) be according to the relationship:

$$L_n = \frac{L - min(L)}{max(L) - min(L)} \tag{9}$$

After this, the L_n is a normal lightness component that is improved using CLAHE. There are two steps to the CLAHE method. First: It is the division of the image into many areas that do not overlap and are almost equal in size. Second, it computes the graph for each region. Then, we get a segment term for cut-off graphs. Each histogram is redistributed in a professional manner so that its height does not exceed the specified segment limit. By β the section term is obtained, which is described as in the following equation [22]:

$$\beta = \frac{M\,N}{L}\left(1 + \frac{\alpha}{100}\ (S_{max} - 1)\ \right) \tag{10}$$

where β is the clip limit, $M \times N$ is the number of pixels in each region, L is the number of grayscales, α is a clip factor $(0 - 100)$, and Smax is the maximum allowable slope. From eq. (10), if $\alpha = 0$, then the clip limit = MNL. However, S_{max} should set to four for still images.

2.3 Reverse transformation

The colors in the image are retrieved by relying on the inverse transformation from Lab space to RGB space, according to the following [23]:

$$L_{ne} = L_{ne} \times 10 \tag{11}$$

$$X = X_n \begin{cases} \left(\frac{L^*}{166} + \frac{a^*}{500} + \frac{16}{166}\right)^3 & if\ L^*\ > h, \\ \frac{1}{7.787}\left(\frac{L^*}{116} + \frac{a^*}{500}\right) & if\ L^*\ \leq h, \end{cases} \tag{12}$$

$$Y = Y_n \begin{cases} \left(\frac{L}{116} + \frac{16}{166}\right)^3 & if\ L\ \ > h, \\ \frac{1}{7.787}\ \frac{L^*}{116} & if\ L\ \ \leq h \end{cases} \tag{13}$$

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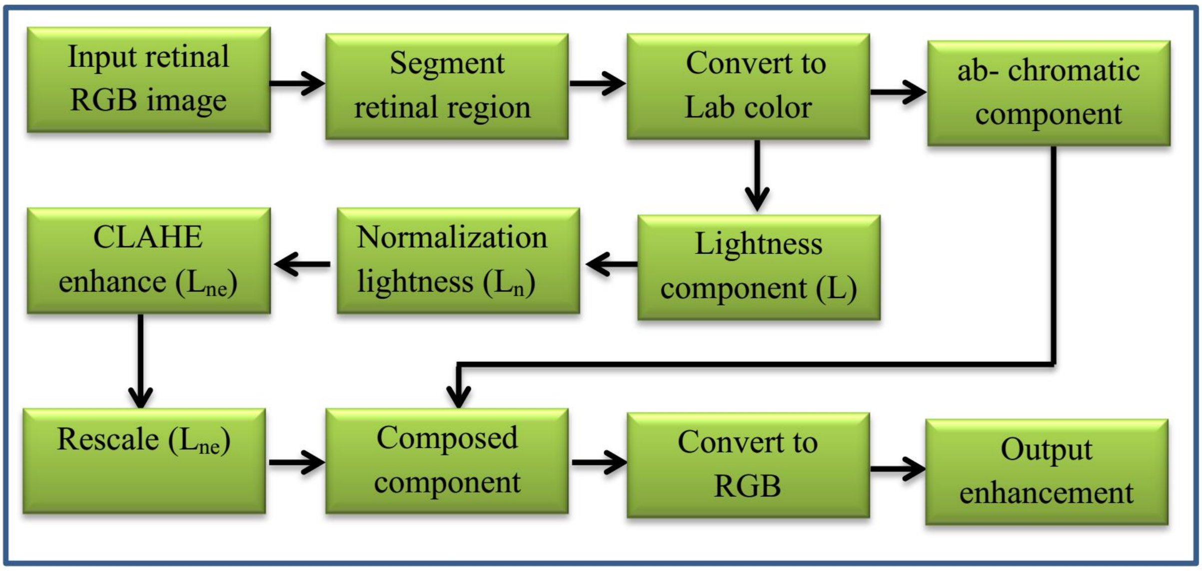
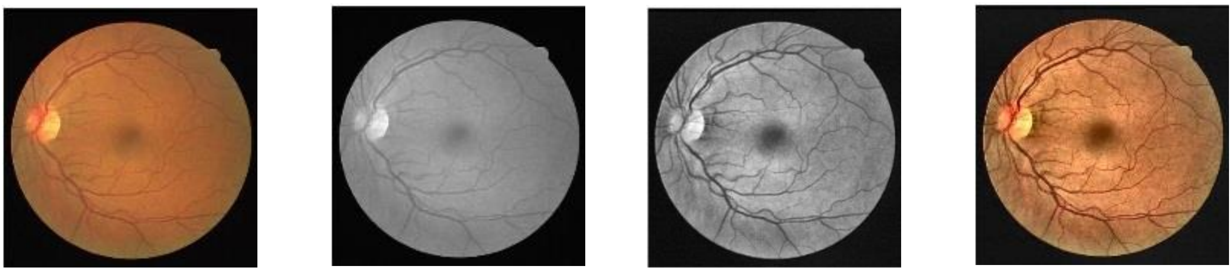


Figure. 2 The scheme represents the proposed method



(a) (b) (c) (d)

Figure. 3 The stages of a suggested algorithm: (a) original image, (b) lightness, (c) CLAHE, and (d) final enhancement

$$z = z_n \begin{cases} \left(\frac{L}{116} - \frac{b^*}{200} + \frac{16}{116}\right)^3 & if\ L\ > h, \\ \frac{1}{7.787}\left(\frac{L}{116} - \frac{b^*}{200}\right) & if\ L\ \leq h, \end{cases} \quad (14)$$

$h = 7.9996$, Fig. 2 shows the steps proposed method, and Fig. 3 illustrated these steps with images.

3. Quality assessment

To measure the quality of the improvement of the retinal images, several quality measures were used, some of which are referenced, such as peak signal to noise ratio (PSNR), and some are non-referenced, such as contrast enhancement measurement (CEM) and entropy.

The equation of PSNR is [24] :

$$MSE = \frac{1}{M \times N} \sum_{m=1}^{m} \sum_{n=1}^{n} [f(m,n) g(m\ ,n)\ ]^2 \quad (15)$$

$$PSNR = 20 \times\ log_{10}\left(\frac{255}{\sqrt{MSE}}\right) \quad (16)$$

where $f\ (m,n)$ is the original image, $g\ (m,n)$ is the approximate version (the decompressed image), and M, N is the dimensions of the images. A lower value of MSE means less error as is evidenced by the inverse relationship between $MSE\ and\ PSNR$, and this translates to a higher value of $PSNR$.

The CEM is dependent on the mean of the local contrast index [15]:

$$C_{local} = \frac{max-min}{max+min} \quad (17)$$

C_{local}: the local contrast index $(min > 0\ and\ Clocal\ < 1)$, where *max* and *min* represent respectively the maximum and minimum intensity values within $a\ N \times N$. in this study we used $N = 50$.

The entropy scale is determined by the maximum amount of information in the medical image that scale is selected. Determine the entropy as [25]:

$$En = -\sum_i p(i)\ log\big(p(i)\big) \quad (18)$$

where $p(i)$ being the probability of grey images.

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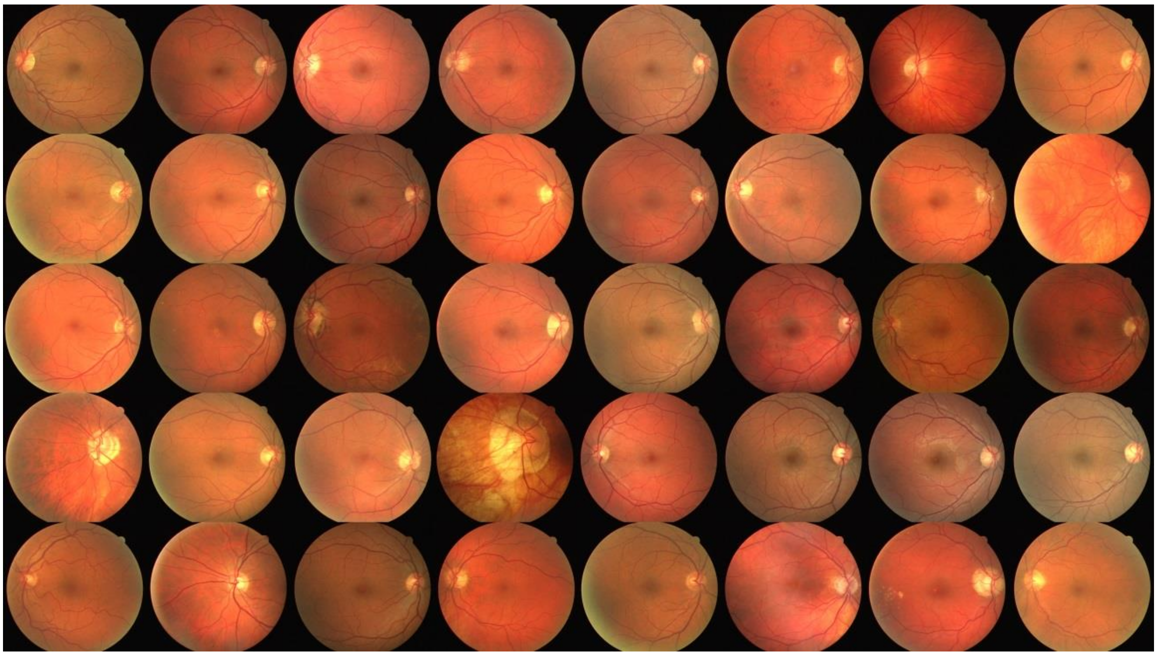


Figure. 4 The driver rental images data [26]

4. Result and discussion

In this paper, a new algorithm has been proposed to enhance retinal images. All algorithms are programmed using the Matlab (r2020a) by i7 RAM 12 GB and proses 2.7 GHz. Driver retinal data [26] was used in this study. This data includes 40 images with size 565×584 and TIF type as in Fig. 4. Retinal images are enhanced using a number of methods - PCAURM, MCHE, LCA, FLSMF, CLAHE, CEA, and suggested (Sug.) algorithm. To find out the efficiency of enhancing these images, several quality measures were used, which are PSNR, EN, and CEM, Table 1 and Fig. 5 represents the average of the quality measures for the enhanced retinal images (40 images). We note that the greatest value (EN and CEM) was for the proposed method, followed by the method CLAHE, and then the other methods, and the lowest result was CEA. In the entropy scale, the proposed method was followed by MCHE then the other methods. In Fig. 6, three images (a, b, & c) with the label (26, 36, & 37) in the diver data were selected for subjective quality assessment and histogram plot. Figs. 7 and 8 represent an enlarged part of an improved image (a and b). In the proposed method, we notice obtaining more color information and an increase in details, as well as an increase in the value of illumination followed by CLAHE. Fig. 9 represents (c image) that have been enhanced using various enhancement methods through subjective observations, we note that the best enhancement (increase in contrast) was for the proposed method, followed by the CLAHE method.

Table 1. Average of a quality enhanced retinal images

Method	CEM	ENTROPY	PSNR
Sug.	**0.5746**	5.6338	24.4281
PCAURM	0.4029	4.7929	**21.6264**
MCHE	0.4829	**5.6270**	**22.5432**
LCA	0.5082	5.3694	**19.8072**
FLSMF	0.4294	5.4750	**13.8380**
CLAHE	0.5615	5.6160	**24.8657**
CEA	0.4010	4.8354	**26.6610**

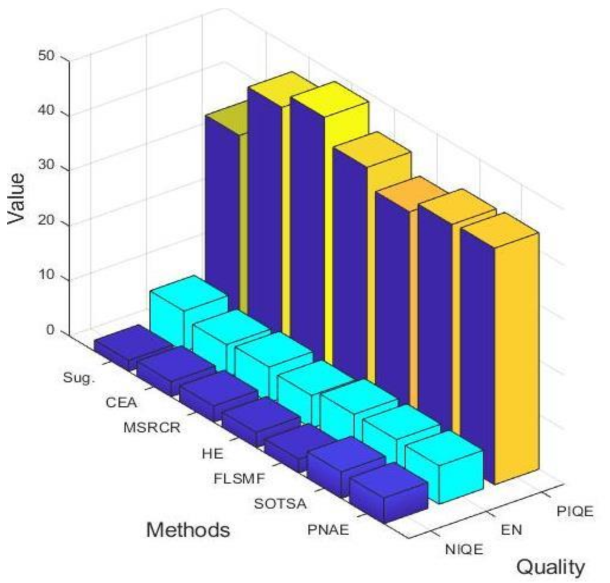


Figure. 5 3D bar plot of the average quality

The same enhancement behavior is reflected on the histogram distribution in Figs. 10 and 11. We note that the best wide distribution ranges for the red, green, and blue channels were for the proposed method, followed by CLAHE, while the rest of the

(a) (b) (c)

Figure. 6 Images: (a) image a label 26, (b) image b label 36, and (c) image c label 37

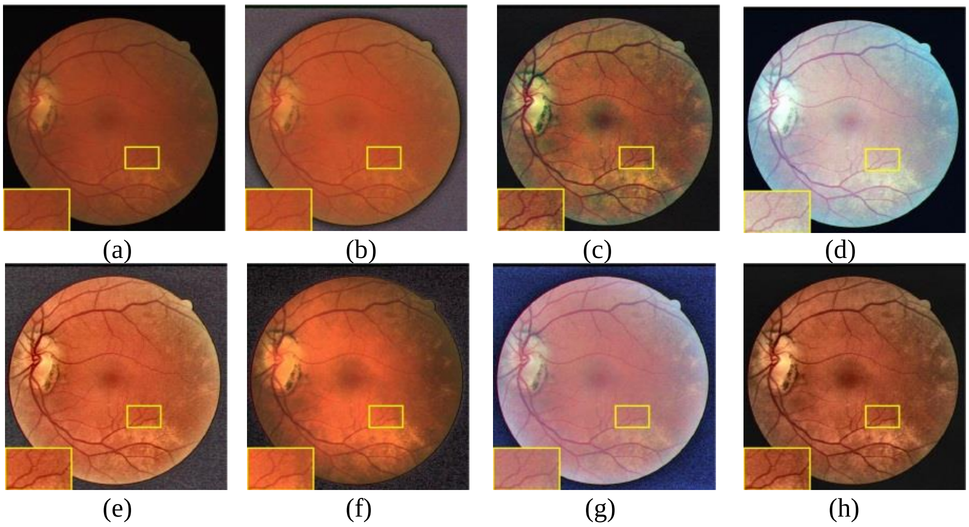
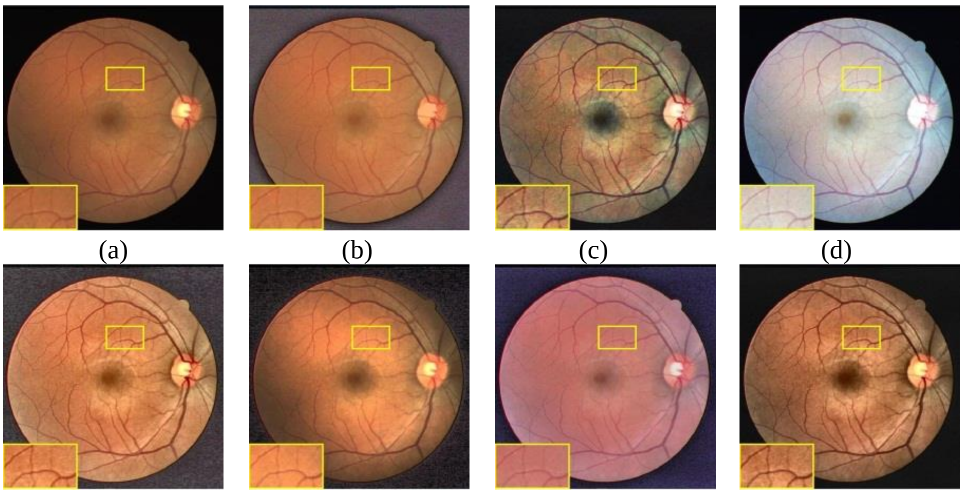


Figure. 7 Images a enhanced using several methods and its include an enlarged part: (a) original a, (b) CEA, (c) CLAHE, (d) FLSMF, (e) LCA, (f) MCHE, (g) PCAURM, and (h) Sug

methods varied in improvement, this indicates the success of the proposed method in increasing the brightness and contrast of the improved images.

4. Conclusion

In this study, the aim was to improve the retinal images with low contrast and irregular lighting by adopting a new algorithm. The suggested method was compared with the algorithms PCAURM, MCHE, LCA, FLSMF, CLAHE, and CEA by using quality assessment depending on PSNR, ENTROPY, and CEM. By analyzing the results, we can conclude that the suggested algorithm succeeded in enhancing retinal images better than other methods and had high values for the rate for PSNR (24.4281), ENTROPY (5.6338) and CEM (0.5746) depending on driver retinal data.



(e) (f) (g) (h)

Figure. 8 Images b enhanced using several methods and it includes an enlarged part: (a) original b, (b) CEA, (c) CLAHE, (d) FLSMF, (e) LCA, (f) MCHE, (g) PCAURM, and (h) Sug

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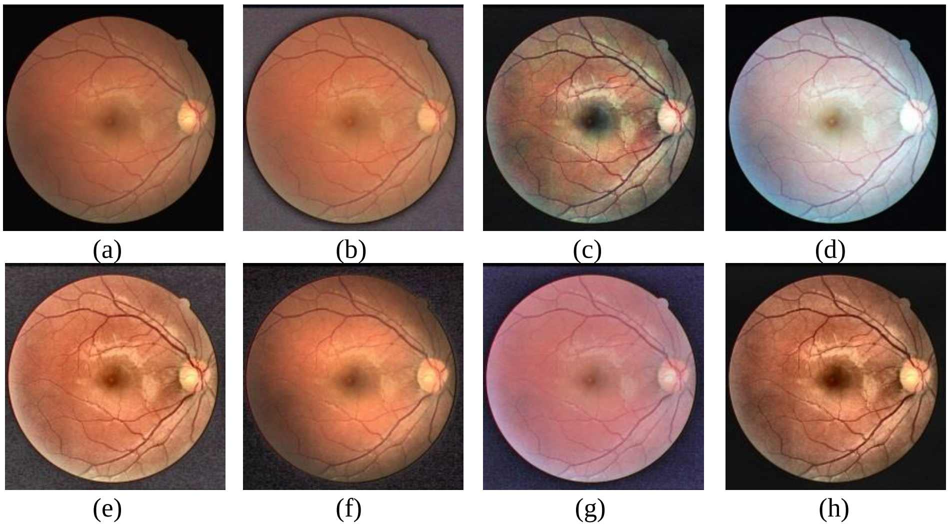

Figure. 9 Images c enhanced using several methods: (a) original c, (b) CEA, (c) CLAHE, (d) FLSMF, (e) LCA, (f) MCHE, (g) PCAURM, and (h) Sug

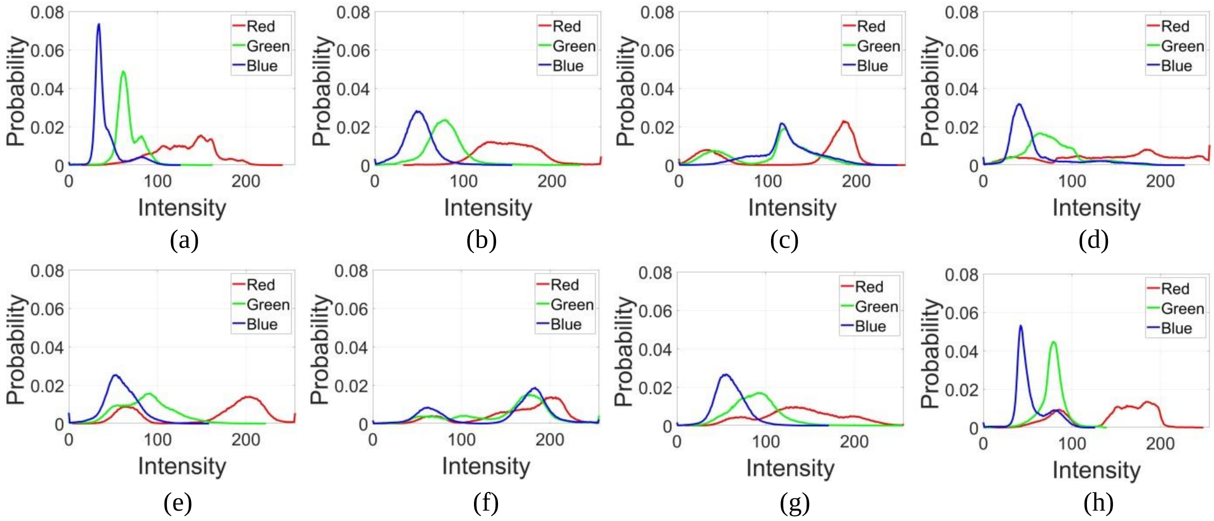

Figure. 10 Histograms of the retinal images a that enhanced using several methods: (a) original a, (b) CEA, (c) CLAHE, (d) FLSMF, (e) LCA, (f) MCHE, (g) PCAURM, and (h) Sug

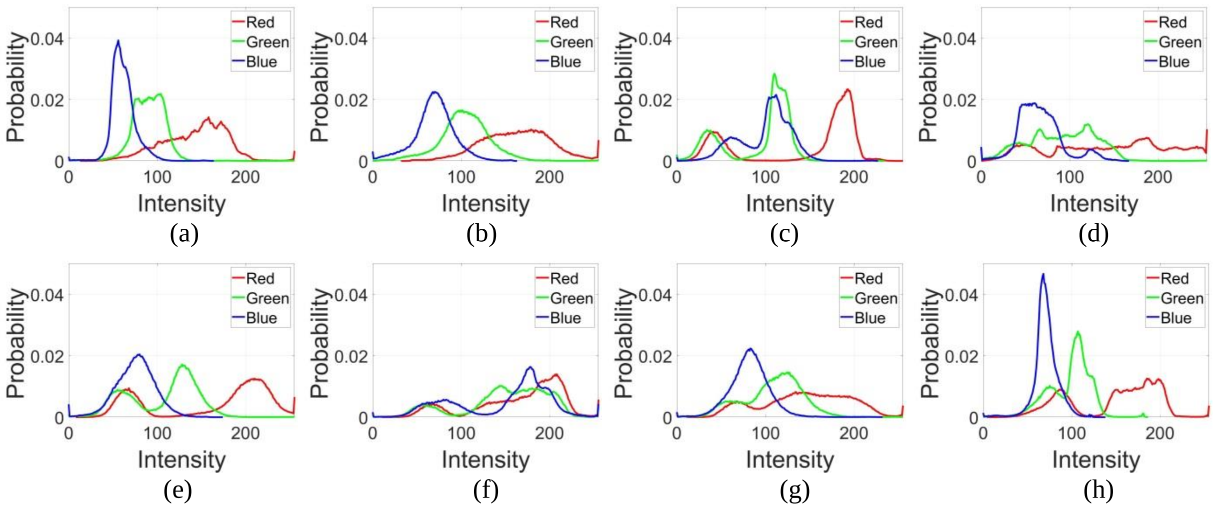

Figure. 11 Histograms of the retinal images b that enhanced using several methods: (a) original b, (b) CEA, (c) CLAHE, (d) FLSMF, (e) LCA, (f) MCHE, (g) PCAURM, and (h) Sug

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