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Low Lightness Image Enhancement Using Modified DCP Based Lightness Mapping in Lab Color Space

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Abstract: Enhancement of images with low light has become an important role in the field of digital image processing, especially when you take the image at low or irregular lighting levels. In this study, a new algorithm was proposed to enhance images with low light based on the development of the Dark Chanel Prior (DCP), Where the image was first improved using this DCP then the lightness component in (Lab) space was improved using the sigmoid mapping. The proposed method was compared with several algorithms by using non-reference quality measures as naturalness image quality evaluator and image quality evaluator using LIME data. By analyzing the results we note the success of the proposed method in improving images with low light, with obtaining the best contrast and lightness compared to the rest of the methods, where the proposed method obtained the best quality values of natural image quality evaluator (3.462) and perception image quality evaluator (35.714).

Keywords: Contrast enhancement, DCP, Sigmoid function, Low lightness, Lab color space.

1. Introduction

Processing color images included two main parts [1], first is full-color processing as real-time color images include colors in the visible spectrum (true colors) and their processing, and then is a false color processing includes color images similar to true colors that fall outside the visible spectrum. Many processing techniques can be performed on images such as medical images, object detection [2, 3] surveillance, tracking, underwater images [4, 5], etc. images taken in low illumination have poor lighting and low contrast [6, 7]. Recently, the importance of processing low-light images has increased, for many reasons, including image information for processing and interpretation of its data in order for the machine to understand it, and for the development of modern simulation systems [8]. At the present time, a new trend has been made to increase the quality of the color image by improving the lighting and internal diversity in order to obtain an image similar in features to the image seen by the human eye. Many previous studies deal with the topic of enhancing the color images.

Y. Chiu et al introduced contrast enhancement based on an adaptive gamma correction and cumulative lightness distribution [9], This algorithm gives a good improvement in medium-light areas however, when improving images with low light, an error occurs in color information.

H. lin and Z.shi proposed an algorithm to improve the contrast in the color image, and it is one of the algorithms that are of great importance in improving images, this algorithm is based on the theorem Retinex theory, which includes several basic stages, the first is the single-scale retina (SSR), multi-scale retinex (MSR) and multi-scale retinex with color restoration(MSRCR), Which depends on the logarithmic transformation of the Gaussian convolution, taking into account the color restoration [10], this algorithm gives a good enhancement when the lighting is medium, but when the lighting is low will be accursed haloes effects.

Z. Zhou et al proposed a parallel adaptive enhancement algorithm to improve images alternately with low light and high light, and they adopted in their research the nonlinear parallel adaptive optimization technique for contrast improvement. In particular, they adopted the Taylor series for the lighting component, and the color restoration was based on the ratio between the old and the improved lighting. However, despite the improved lighting in the images, their research in some new areas introduced color errors [11] , and then they introduced an algorithm for low lightness image enhancement this method depending on a second-order Taylor series approximation (SOTSA), the enhancement in this method ensures special importance for the edges region [12], this method has a good improvement in image lightness and local contrast, in addition to protecting edge information. X. Fu et al proposed an algorithm to improve color images captured at week luminance levels, this algorithm includes the fusion technique, taking into account the improvement of illumination based on the sigmoid transformation and histogram normalization, through their results [13], they got a good improvement for the areas with less luminosity. G. Bhupendra and T. Agarwal introduced Contrast Enhancement Approach (CEA) based on transform (YC_BC_R) where the lightness component was processed while preserving the color information, and the lighting channel was improved by relying on low pass filter and sigmoid mapping [14], this method succeeded in obtaining a good improvement of the low lightness image.

N. Singh and A. Bhandari proposed an algorithm to improve the low-light images, where they used the principal component analysis. This was done by using the reflection model principal component analysis using reflection model (PCAURM), and this algorithm worked in an adaptive way with the images with low light (darkness) [15]. This method has good results in low-light images.

J. Lisani suggested an algorithm for the local contrast enhancement approach based on a mean Curvature Motion (MCM), and weight map, this method includes an adaptation gamma correction (AGC) and logarithm mapping, this algorithm was able to provide a good improvement for the poorly lit areas [16].

Hazim G. et al introduced an algorithm that has been proposed to improve color images based on Fuzzy Logic by Stretch Membership Function (FLSMF) [17], this technique included a sigmoid membership function that works on each of the color compounds, this algorithm preserving color detail in terms of improving lightness. Daway. G et al suggested a method using fuzzy logic by power membership function (FLPMF) to improve the brightness and contrast through the use of image processing techniques, the processing was done using the quality measure natural image quality evaluator (NIQE), mean square error in the saturation mean square error in the Hue the algorithm outperformed all methods in terms of improving the lighting and preserving the color details of the images [18].

In this study, we will go to enhance images with low lightness based on DCP using Lab color space, where the lighting component (L) is processed separately using (Lab) space, while preserving the color information (ab). The suggested method retrieves lighting and contrast information without any color distortion compared to other methods.

2. Proposed method

The proposed method for improving low-light images depends on the technique (DCP) in RGB color space and then using the (Lab) color space to enhancing the lighting component using sigmoid mapping, according to the following steps.

2.1 DCP Enhancement

It is one of the techniques for improving the contrast in hazy images, the model describing dust or fog in a scene is given [19]:

$$I\,(\,i) = J\,(\,i)\,tr(i) +\ Ar\,(\,1 - tr(\,i)) \qquad (1)$$

Thus, DCP for an arbitrary image Jn is defined as [19]:

$$J_{\,dark}(\,i) = min_{n\,\epsilon\,\{r,g,b\}}\,(min_{\,y\epsilon\,\Omega\,(i)}\,(Jn\,(y))) \qquad (2)$$

where Jn is a color data of J and $\Omega\,(i)$ is a local patch has i center, the intensity of dark channel of Jn is low and go to be zero where Jn is an outdoor haze or free image and then:

$$J_{\,dark}(\,i) \cong 0 \qquad (3)$$

and the transmission component can be calculated by [19]:

$$tr\,(i) = 1 - w\_min_{n\,\epsilon\,\{r,g,b\}}\,(min_{n\,\epsilon\,\{r,g,b\}}\,\frac{I^n(y)}{Ar}) \qquad (4)$$

The transmission value is refined by using map soft mapping. If the haze is enhanced, the image appears unnatural, so the value $(0 < w < 1)$, w is fixed at 0.95, and the optimal value of atmospheric light $Ar = 0.1$, in this study we used patch size (15×15) [7]. The final enhancement is [19]:

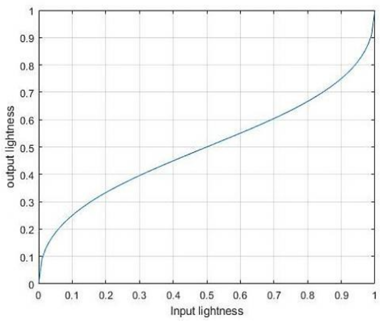

Figure. 1 A sigmoid mapping [17]

$$J(i) = \frac{I(i) - Ar}{\max(tr(x), 0.1)} + Ar \quad (5)$$

Sigmoid mapping by using Lab color space, this space is one of the regular color spaces the component can be funding by [20]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.41 & 0.35 & 0.18 \\ 0.21 & 0.71 & 0.07 \\ 0.01 & 0.11 & 0.95 \end{bmatrix} . \begin{bmatrix} r \\ g \\ b \end{bmatrix} \quad (6)$$

$$f(rm) = \begin{cases} \sqrt[3]{m} & for\ m > e, \\ 7.787m + \frac{16}{116} & for\ m \le e. \end{cases} \quad (7)$$

$$L = \begin{cases} 116\left(\frac{Y}{Y^n}\right)^{\frac{1}{3}} - 16 & \frac{Y}{Y^n} > m \\ 903.3\left(\frac{Y}{Y^n}\right) & \frac{Y}{Y^n} \le m \end{cases} \quad (8)$$

($m = 0.008856$), It is preferable that the values of L are normalized $(0,1)$ by using:

$$Ln = L/100 \quad (9)$$

Improvement of brightness and contrast is done by, the Sigmoid mapping [17]:

$$L_s = \frac{1}{(1 - (\frac{\sqrt{1-\mathrm{Ln}}}{\mathrm{Ln}}))} \quad (10)$$

In this function, at low-intensity levels of less than half, we can see an increasing output intensity value, in the moderate-intensity levels, the intensity values remain the same, whereas at high-intensity levels below high, the intensity output becomes lower values, as shown in Fig. 1.

The final enhancement gets from the inverse transformation from Lab space to RGB space, according to the following [21]:

$$L_{sc} = L_s \times 100 \quad (11)$$

$$X = X_n \begin{cases} \left(\frac{L_{sc}}{166} + \frac{a}{500} + \frac{16}{166}\right)^3 & if\ L_s > h, \\ \frac{1}{7.787}\left(\frac{L_{sc}}{116} + \frac{a}{500}\right) & if\ L_s \le h, \end{cases} \quad (12)$$

$$Y = Y_n \begin{cases} \left(\frac{L_{sc}}{116} + \frac{16}{166}\right)^3 & if\ L_s > h, \\ \frac{1}{7.787}\frac{L_{sc}}{116} & if\ L_s \le h \end{cases} \quad (13)$$

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

Where $h = 7.9996$, and then

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.22 & -1.51 & -0.49 \\ -0.96 & 1.87 & 0.04 \\ 0.07 & -0.20 & 1.05 \end{bmatrix} . \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad (15)$$

Fig. 2 illustrated the steps suggested method for low lightness image, and Fig. 3 shows a block diagram of its.

3. Result and discussion

In this research, very low-light images were enhanced on the basis of the suggested (sug.) algorithm and other algorithms (CEA, MSRCR, HE, FLSMF SOTSA, and FLPMF). All algorithms were used in Matlab program [(Ra 2018) with PC, 2.7 GHz core i7], depending on LIME data [22]. The data contained 10 images with type BMP, as

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

Figure. 2 In: (a) original image, (b) DCP enhancement, (c) lighting component, (d) Sigmoid transform, and (e) image enhancement

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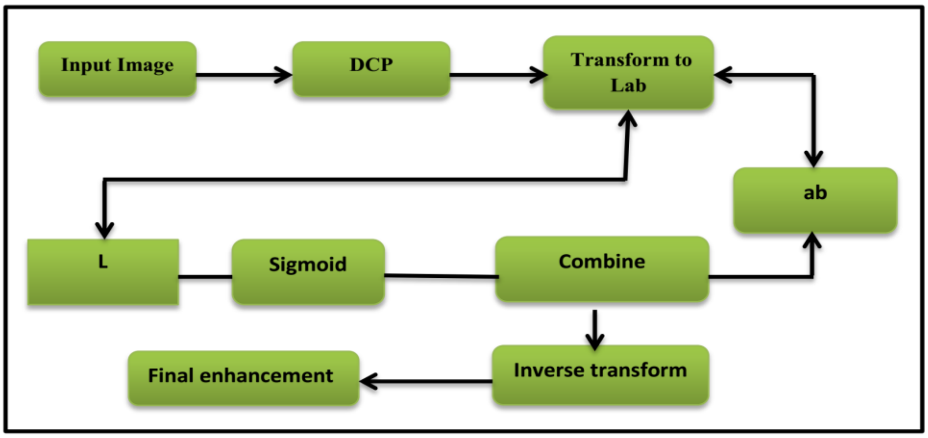
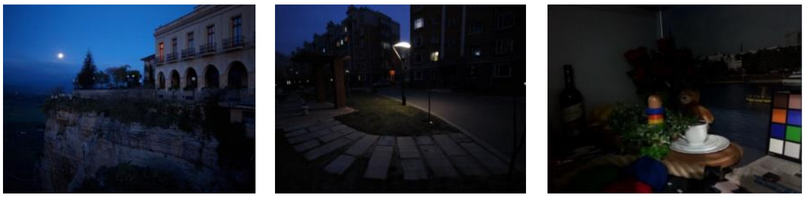


Figure. 3 A block diagram of the suggested algorithm

Figure. 4 The LIME data [24]



(a) (b) (c)

Figure. 5 The images were selected form LIME dada

Table 1. The average qualities

Method	NIQE	PIQE
Sug.	3.462	35.714
CEA [14]	4.378	45.628
MSRCR [10]	6.766	48.467
HE [1]	4.7141	43.959
FLSMF [17]	4.591	40.475
SOTSA [12]	5.946	42.829
FLPMF [18]	3.624	36.482

illustrated in Fig. 4, and in Fig. 5 we chose three images (a, b, & c). Several non-reference quality measurements as NIQE [23] and perception image quality evaluator (PIQE) [24], were adopted to obtain the efficiency of enhancing low-light images. Table 1 shows the average quality of the non-reference measures. The best results were obtained from the proposed method, with obtaining the lowest values of two scales (NIQE and PIQE), this means increased color information in the enhanced images. The same behavior could be found in Table

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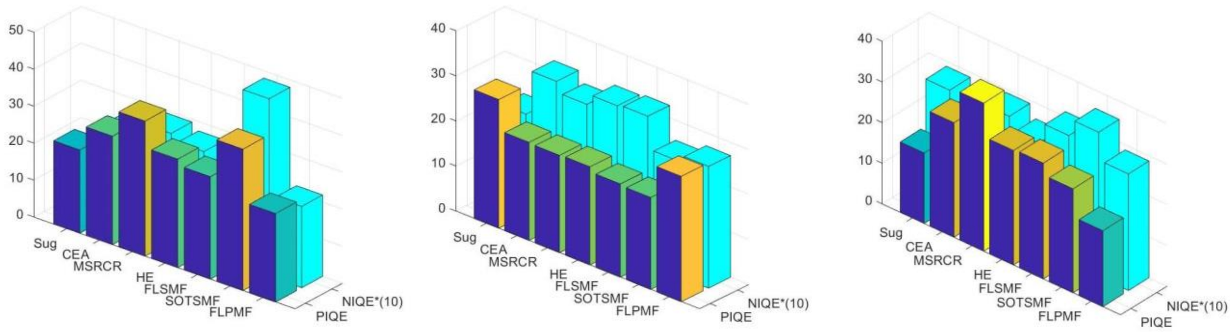
2 when choosing three images from the data, as shown in Fig. 6, which illustrates the 3D bar plot for Table 2. Figs. 7, 8, and 9 represent the third selected image, which was enhanced by all methods. The best improvement was observed in the proposed method, followed by the method FLPMF. To see the ability to improve, an area of the image_a was selected and enlarged as in Fig. 7, we can see the proposed method succeeded in obtaining high contrast and chromatic retrieval for a very light area without color error or color loss (go image to grey). The distribution of histograms for images _c was represented in the Fig. 10, where the proposed method achieved wider ranges of improvement for the red, green, and blue components than the other methods.

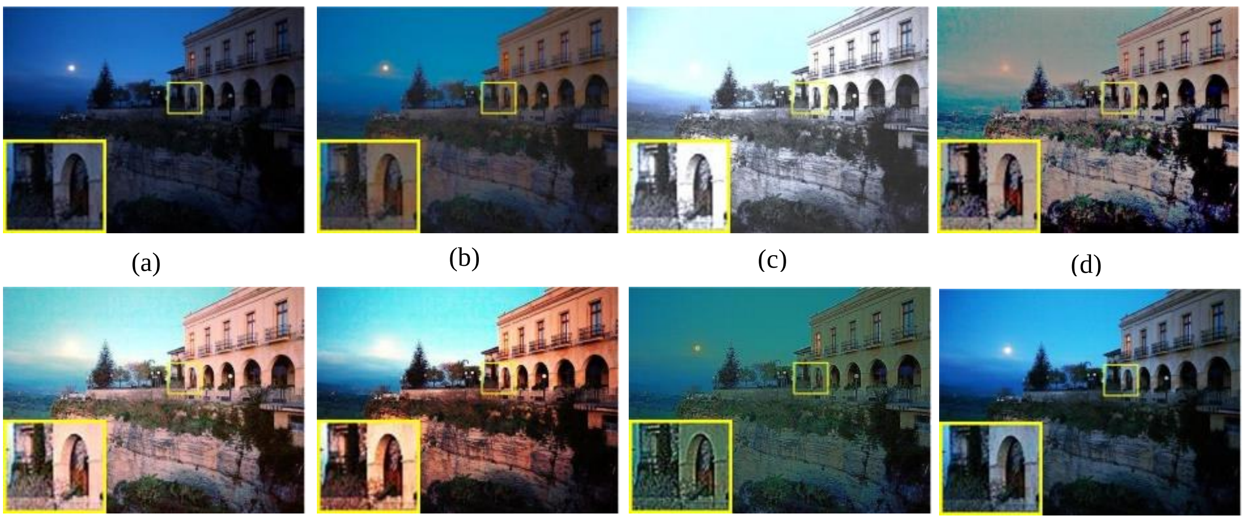
Table 2. The Qualities for enhanced images (a, b, & c)

Image _a			Image _b			Image _c		
Method	**NIQE**	**PIQE**	**Method**	**NIQE**	**PIQE**	**Method**	**NIQE**	**PIQE**
Sug.	**1.93**	**22.51**	**Sug.**	**2.23**	28.55	**Sug.**	2.88	**17.31**
CEA	2.75	29.34	**CEA**	3.23	21.77	**CEA**	**2.61**	28.19
MSRCR	2.93	36.53	**MSRCR**	2.99	21.60	**MSRCR**	2.92	36.42
HE	2.75	29.34	**HE**	3.23	21.77	**HE**	2.61	28.19
FLSMF	2.49	27.71	**FLSMF**	3.27	20.69	**FLSMF**	3.13	28.49
SOTSA	4.80	38.27	**SOTSA**	2.55	**20.39**	**SOTSA**	3.552	**25.58**
FLPMF	2.20	23.96	**FLPMF**	2.70	27.80	**FLPMF**	2.88	18.69



(a) (b) (c)

Figure. 6 The pars plot for qualities averages is in Table 1: (a) Image_a, (b) Image_b, and (c) Image_c



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

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

Figure. 7 Comparisons of low-light image_a enhancement results with zoom details: (a) Image_a, (b) sug, (c) CEA, (d) MSRCR, (e) HE, (f) FLSMF, (g) SOTSA, and (h) FLPMF

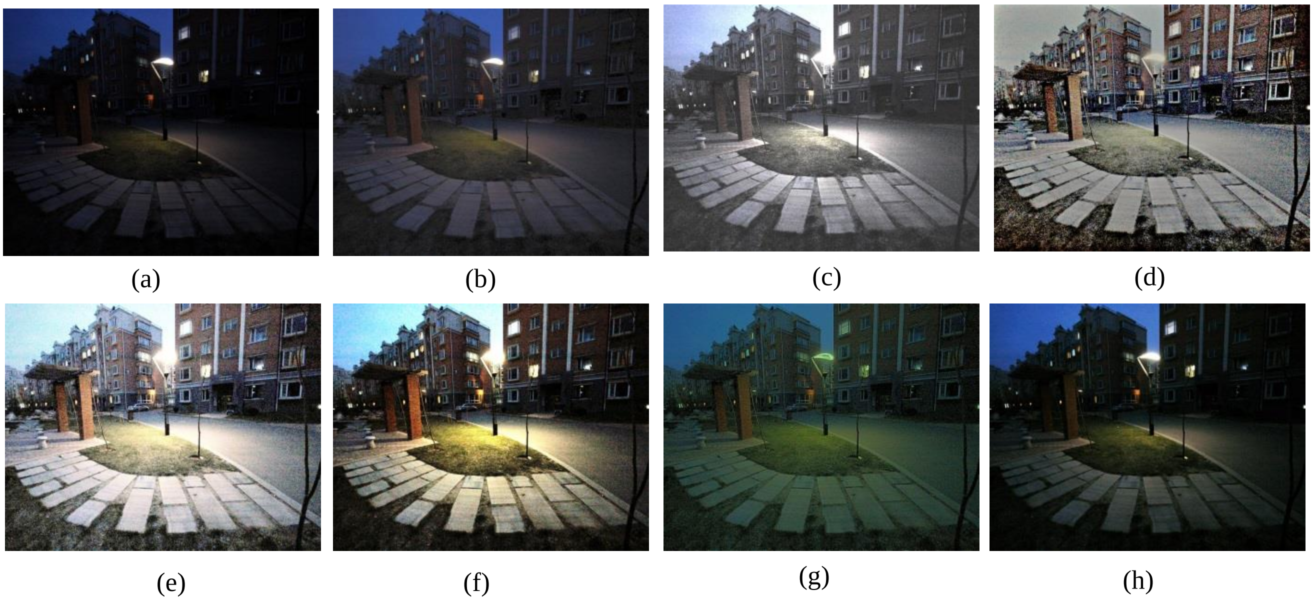


Figure. 8 The Image_b is enhanced using various methods: (a) Image_b, (b) sug, (c) CEA, (d) MSRCR, (e) HE, (f) FLSMF, (g) SOTSA, and (h) FLPMF

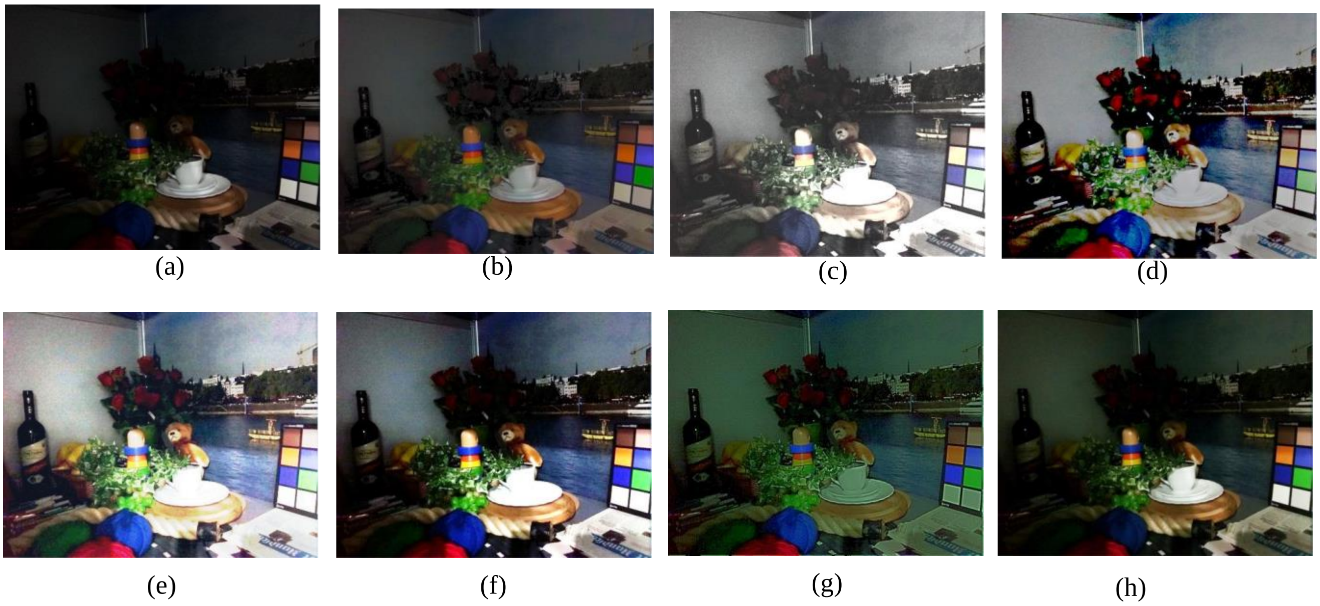


Figure. 9 The Image_c is enhanced using various methods: (a) Image_c, (b) sug, (c) CEA, (d) MSRCR, (e) HE, (f) FLSMF, (g) SOTSA, and (h) FLPMF

4. Conclusion

In this paper, low-light images were improved based on DCP-based sigmoid mapping in the lightness component by LAB color space, LIME data were used in this study. The proposed method was compared with several other methods by using CEA, MSRCR, HE, FLSMF, SOTSA, and FLPMF, and non-reference quality measures NIQE and PIQE. The results showed that the proposed method succeeded in improving images with very low light. The best quality values of 3.462 and 35.714 were obtained for NIQE and PIQE, respectively.

Conflicts of interest

The authors declare no conflict of interest.

Author contributions

Hazim G. Daway has contributed to the design and implementation of the research by using Matlab. Rafid Abbas Ali and Noor Jabbar Abraham have supervised the written paper and providing the necessary data. All authors approved the final version.

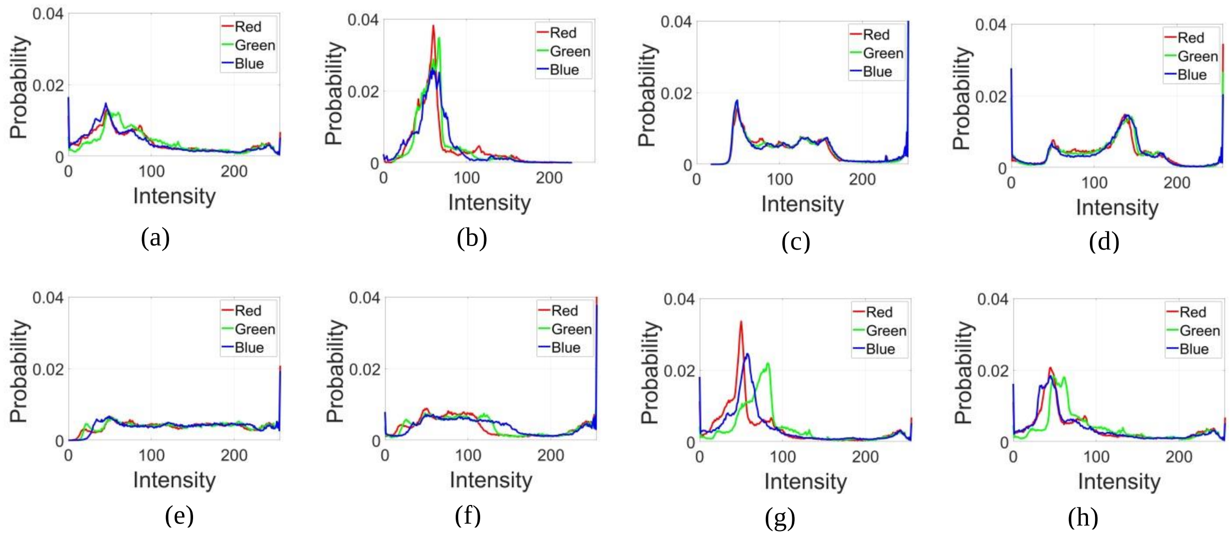


Figure. 10 A histogram of the image_c is enhanced using various methods: (a) Image_c, (b) sug, (c) CEA, (d) MSRCR, (e) HE, (f) FLSMF, (g) SOTSA, and (h) FLPMF

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A notation list

Symbol	**Abbreviation**
a	Chromatic component in Lab color space
Ar	Aatmospheric light
b	Chromatic component in Lab color space
B	Blue component in basic color space
G	Green component in basic color space
I	Observed intensity in the hazy image
J	Scene radiance
J_{dark}	Dark channel of scene radiance
Jn	Color channel of scene radiance
L	Lightness component in Lab color space
Ln	Normalize Lightness component
Ls	Lightness mapping by Sigmoid function
Lsc	Rescale Lightness mapping
R	Red component in basic color space
tr	Transmission map
X	Red component in XYZ space
Y	Green component in XYZ space
Z	Blue component in XYZ space
Ω	Local patch