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Enhancement of Lightness Image Based on DCP with Color Restoration and Lightness Mapping

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Abstract: Improving low-light images is used in many medical, military, and other applications, such as classification, detection, and increasing the clarity of targets. In this study, we improved low-light images by relying on three main techniques. The first is (DCP), the second is color retrieval, and the third is improving the lighting component based on the Lab color space, where the color components are isolated from the light, and then mapping is done using intensity stretch and (adapted histogram equalization). LOL data (containing 485 low-light images) were enhanced, with two types of standards being reference peak signal to noise ratio (PSNR) and non-reference scalas as entropy (EN), average gradient (AG), and natural image quality evaluator (NIQE). By analyzing the results, the proposed method obtained an improvement, and the quality standards reached EN (7.550), AG (9.978), NIQE (3.499), and PSNR (15.013) values. Compared to a number of recent algorithms, which indicates its success in increasing the lighting and contrast in these images.

Keywords: CLAHE, DCP, Lab color transform, Low lightness, Contrast enhancement.

1. Introduction

One definition of an image is the two-dimensional function f(x,y). Processing digital images using a digital computer is referred to as the field of digital image processing. Modern digital computers are responsible for the advancement in the field of digital images, in addition to supporting technologies for data transmission, storage, and display. This is because digital images need a lot of storage and processing power [1]. In general, low contrast and high noise are problems in medical images, airspace imaging, satellite images, and even images taken in real life. Noise is decreased, and contrast is improved, to improve image quality [2]. The two types of enhancement techniques are as follows: approaches using the spatial domain and the frequency domain [3, 4]. Currently, the significance of the number of people processing low-light images is increasing [5, 6]. The reasons behind processing images and analyzing their information are for the purpose of machine development and the improving of understanding of contemporary simulation systems. The goal of image enhancement is for the low lightness enhancement model to improve the visibility of objects to reveal details hidden by darkness [3]. Recently, surface-enhanced raman-scattering (SERS) nanoparticles (NPs) have attracted wide interest due to their potential for sensitive and multiplexed biomarker detection. To determine the presence of cancer with high specificity and accuracy, the cell surface has irregular receptors. A multiple panel of cancer biomarkers is imaged by molecular imaging techniques. In this research, the most important advances in tumor imaging using SERS-encoded NPs are identified. Challenges and future directions are briefly presented in this paper by Yu Wang et al. [7]. Hashim et al. [8] suggested an approach to improve images taken in a very low light. There are two steps in this method. The first step includes color restoration by adding a median filter and min filter, and the second one involves lightness mapping that will be used to enhance the lightness component by employing CLAHE and the sigmoid function using quality criteria like entropy and naturalness image quality assessment evaluator (NIQE). This approach has been compared to other algorithms. Image quality analysis The findings prove that the suggested Approach provided the highest entropy values and the lowest NIQE values, which means this method is the best at enhancing low-light images.

Fuzzy logic techniques [9] are one of the methods used for digital image enhancement, which makes the role of this technology very important in image processing, pattern recognition, and computer vision. This technology was developed to enhance the lightness and color contrast in the image, this algorithm was also applied to the lightness component without changing the color component, using only the YIQ color space, it succeeded in improving lighting and contrast, but it did not recover color information well. Abraham et al. [10] proposed a method based on the development of the BLLA algorithm. This method includes improving the lightness based on the BLLA algorithm and using the YIQ color model, they can improve the lightness part by using the sigmoid function without affecting the components of the color, this method succeeded in improving very low-light images and recovering color and lighting information Without any color distortion. Abraham et al. [11] suggested algorithm to improve low-light images, depending on DCP technology and using the LAB space color. This method first improves images in the RGB space using DCP technology, then by using the color space (Lab) they improved contrast in the lightness component by using the sigmoid function. Several methods were compared with this approach, as well as non-reference quality measures (NIQE and PIQE). The algorithm succeeded in enhancing low-light images as well as obtaining the best NIQE and PIQE values. Ren et al. [12] presented a low-rank regularized retinex model (LR3M) to deal with severe noise that has not been dealt with in previous methods. This model aims to improve low-light images and videos and Remove noise. The approach chooses to successively estimate both the illumination and reflection maps. To put it differently, we begin by estimating the piece-wise illumination map independent of the reflection map. The reflectance is then improved using both the original image and the enhanced illumination. That is, using the reflectance map, a low rank prior is required as a first step to muffle commotion. After obtaining the ideal lighting, the final results of the enhancement are produced by combining the gamma-corrected illumination and reflectance. This method is very effective in reducing noise to a minimum, and It succeeded in improving lighting, but it is very poor in increasing contrast and retrieving the original lighting data and colors. Gupta et al. [13] suggested a method using YcbCr to enhance the contrast of dark images with irregular illumination, they converted the image from the RGB model to the YcbCr model and then used the sigmoid membership function on the base layer of the luminance component to improve the illumination. After that, obtained a new base layer and a detail layer for the illuminance component Y, and finally, they obtained an improved image after converting the YcbCr model to RGB. Using quality measures PQM, EN, and RMSC, this method was successful in enhancing the contrast of dark areas with irregular lighting without affecting the details in bright areas.

In this study, we aim to improve dark images using the DCP technique and color restoration. We enhanced illumination using the Lab color model by stretching the lightness and stretching the image contrast. The proposed method succeeded in increasing contrast (details and sharpness in the edge areas) and color information while preserving as much as possible the original lighting.

2. Suggested approach

The suggested method for improving images with low lightness includes using the DCP technique to produce haze-free images and restoring colors by applying two filters, then using the Lab model, then improving the lighting component using lightness stretch and CLAHE, and finally obtaining enhanced images after converting Lab to RGB.

2.1 DCP algorithm and color restoration

The general attenuation model proposes that the physical haze of a landscape in aerial images might represented by the relationship seen in [14]:

$$f(v) = I(v)t_r(v) + Ac(1 - T_r(v)) \qquad (1)$$

where I is the scene's brightness and f is the intensity of the fuzzy image. The ambient light is Ac, and Tr Is the channel for transmission. The attenuation model is solved via the DCP technique. Which is applied to images that are hazy or airborne. in one of the RGB channels at a low intensity as [14]:

$$I_{dark}(v) = m\,in_{i\in(r,g,b)}\left(\min_{y\in R(v)}\left(I_i(y)\right)\right) \qquad (2)$$

Where $R(v)$ denotes the local patch with v as its center point and $I_i$denotes the three channels (red, green, and blue) of i. The DCP method makes the dark channel of Ii's lightness decrease to zero. $I_i$is a haze-free outdoor. (Haze-free image unless extremely bright region) and is demonstrated by:

$$I_{dark}(v) \cong 0 \quad (3)$$

Therefore, the value of the transmission component may be determined by [14]

$$T_r(v) = 1 - d_{min y \in R(v)} \left(\min_{i \in (r,g,b)} \frac{J(y)}{Ac} \right) \quad (4)$$

A transmission can be improved by soft mapping. If the haze or dust is removed, the image loses its natural appearance. Therefore, the value d is set to 0.95 in the equation (0< d <1), and the ideal value of ambient light is Ac = 0.1 (15x15)-pixel patch size, next, the improved Image is provided by [14]

$$I(v) = \frac{j(v) - Ac}{\max\left(T_r(v), 0.1\right)} + Ac \quad (5)$$

Color distortion is one of the things that low illumination causes in the photographs that are captured in this circumstance. Utilizing a method that involves gathering the median and minimum filters for each color component, color restoration can be accomplished. As shown in (*R, G,* and *B*) [8].

$$R' = minfilter\,(R) + medianfilter(R) \quad (6)$$

$$G' = min\,filter(G) + median\,filter(G) \quad (7)$$

$$B' = min\,filter(B) + median\,filter(B) \quad (8)$$

2.2 Lightness enhancement based on lighting stretch and CLAHE

Only the lightness component is enhanced separately based on the Lab color space's color components. This enhancement method increases lightness without causing distortion in the original colors. The following equations transform the image from RGB space to Lab space. [15]:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.41 & 0.35 & 0.18 \\ 0.21 & 0.71 & 0.07 \\ 0.01 & 0.11 & 0.95 \end{bmatrix} . \begin{bmatrix} r(x,y) \\ g(x,y) \\ b(x,y) \end{bmatrix} \quad (9)$$

$$f(r) = \begin{cases} \sqrt[3]{r} & for\, r > e \\ 7.787r + \frac{16}{116} & for\, r \le e \end{cases} \quad (10)$$

$$L^* = \begin{cases} 116\left(\frac{Y}{Y^n}\right) & \frac{Y}{Y^n} > e \\ 903.3\left(\frac{Y}{Y^n}\right) & \frac{Y}{Y^n} \le e \end{cases} \quad (11)$$

$$a^* = 500\left(f\left(\frac{X}{X^n}\right) - f\left(\frac{Y}{Y^n}\right)\right) \quad (12)$$

$$b^* = 200\left(f\left(\frac{Y}{Y^n}\right) - f\left(\frac{Z}{Z^n}\right)\right) \quad (13)$$

(e=0.008856), It is preferred for the stretched values.

We suggest inputting a low-lightness image and performing a lightness stretch, the means and standard deviations are determined. Second, the low light image's maximum and minimum values for the lightness channel are calculated [16].

$$L_{max} = L_{mean} + \gamma L_{std} \quad (14)$$

$$L_{min} = L_{mean} - \gamma L_{std} \quad (15)$$

The mean and standard deviation of the component's lighting are represented by L_{mean} *and* L_{std} respectively; γ is a parameter used to control the image dynamic; and represents the c_{max}*and* c_{min} maximum value and minimum of the I channel, respectively. The restored image was obtained by the stretch image [16]:

$$Le = \frac{L - Lmin}{L_{max,} - L_{min}} \quad (16)$$

the L_e is then an ordinary lightness component that is enhanced by CLAHE [15]. The CLAHE approach consists of two parts. First, it is the split of the image into several, almost identically sized, non-overlapping parts. The graph is then calculated for each region. The term "segment" is then introduced for cut-off graphs. Each histogram is carefully redistributed so that its height does not exceed the allowed limit for each segment. via beta, The section term is acquired, which is defined in the equation as [17]:

$$\beta = \frac{MN}{L}\left(1 + \frac{\alpha}{100}(S_{max} - 1)\right) \quad (17)$$

Where L is the number of grayscales, MN is the number of pixels in each local region, Smax is the highest allowed slope, and β is a clip factor (0–100). If α =0 in Eq. (17), the clip limit is equal to $\frac{MN}{L}$. S_{max} should be set to four for still images, though.

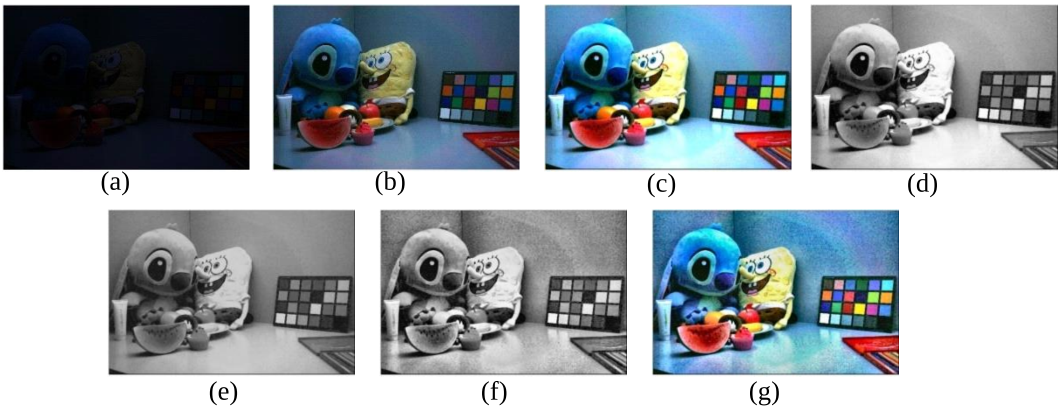

Figure. 1: (a) Input image, (b) DCP enhancement, (c) Color restoration, (d) Lighting component, (e) lightness stretch, (f) CLAHE, and (g) Image enhancement

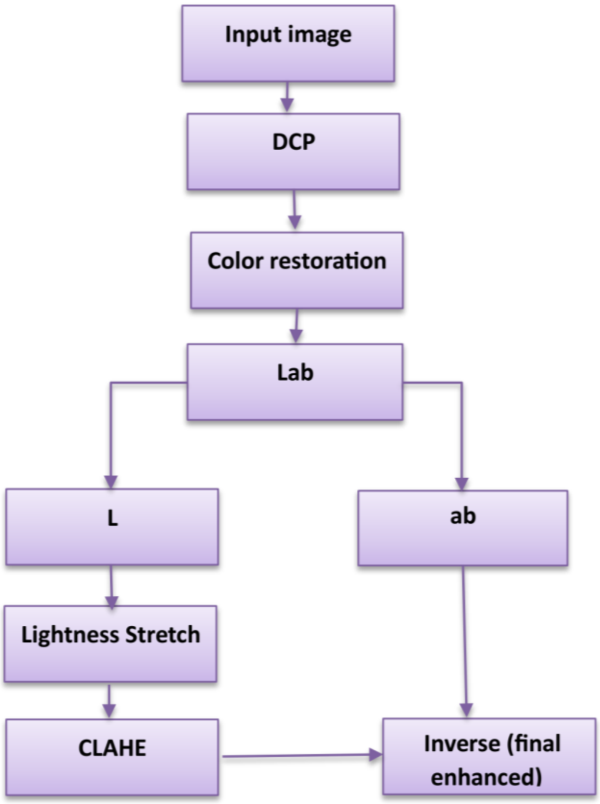

Figure. 2 A block diagram of the proposed method

2.3 Reverse transformation and enhancement image

According to the following, to obtain the colors in the image, we inversely transform from Lab space to RGB space [18].

$$L_{ne} = L_e \times 100 \tag{18}$$

$$X = X_n \begin{cases} \left(\frac{L^*}{166} + \frac{a^*}{500} + \frac{16}{166}\right)^3 & if\ L^* > h \\ \frac{1}{7.787}\left(\frac{L^*}{116} + \frac{a^*}{500}\right) & if\ L^* \leq h \end{cases} \tag{19}$$

$$Y = Y^n \begin{cases} \left(\frac{L^*}{116} + \frac{16}{166}\right)^3 & if\ L^* > h \\ \frac{1}{7.787}\frac{L^*}{116} & if\ L^* \leq h \end{cases} \tag{20}$$

$$Z = Z^n \begin{cases} \left(\frac{L^*}{116} - \frac{b^*}{200} + \frac{16}{116}\right)^3 & if\ L^* > h \\ \frac{1}{7.787}\left(\frac{L^*}{116} - \frac{b^*}{200}\right) & if\ L^* \leq h \end{cases} \tag{21}$$

Where h=7.9996, and then

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 3.22 & -1.51 & -0.49 \\ -0.96 & 1.87 & 0.04 \\ 0.07 & -0.20 & 1.05 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{22}$$

3. Image quality assessment

In this study, several non-referenced and referenced quality measures were used, as follows.

3.1 Entropy (EN)

is a crucial metric for assessing image quality, indicating the amount of information present in an image, the image keeps the detailed content as the entropy value increases the following equation can be used to describe as [1].

$$EN = \sum_{i=0}^{255} p(a) \log p(a) \tag{23}$$

Where p(a) represents the likelihood that image pixel (a) will appear.

3.2 Average gradient (AG)

The image's AG value can represent discreet contrast and texture variations as well as, to an extent, indicate the image's clarity. The equation in which the AG value is determined is shown in eq [19].

$$AG = \frac{1}{M \times N} \sum_{i=1}^{row} \sum_{j=1}^{col} \sqrt{\Delta_{level} f(i,j)^2 + \Delta_{vertical} f(i,j)^2} \quad (24)$$

The row and column numbers of the improved image are M and N, respectively.

3.3 Natural image quality evaluator(NICE)

The natural image quality evaluator (NIQE) is an image quality analyzer that may be used to calculate variations from the original image. A better perceptual quality is indicated by a smaller value when comparing the tested image to the default model. The average local deviation field is used to represent the NIQE [20].

$$\delta = \sum \sum_{i,j} \sigma(i,j) \quad (25)$$

Where σ the mean filter, and δ is the local sharpness.

3.4 Peak signal to noise ratio (PSNR)

The PSNR measurement is used to evaluate the quality of a distorted image in relation to its original version. A calculated PSNR value shows the quality approximation between the original image and the distorted image. The higher value of PSNR. The enhanced image processing.the greater the PSNR value. The more effective image processing.The greater the PSNR value, the better in image processing. The PSNR can be written as [21].

$$PSNR = 10 \log_{10} \left(\frac{MAX^2}{MSE} \right) \quad (26)$$

The maximum value of a pixel in an image is known as MAX. When pixels are displayed in an 8-bit format, MAX is 255.

4. Results and discussion

In this study, low-light images were enhanced based on LOL data [22], which contain 485 lowlight images and, at the same time, contain good lighting images. One of the most important strengths of this data is that reference quality measurements such as PSNR can be calculated, and in this study, non-reference quality measurements can be calculated. To calculate the contrast, the entropy was measured. To calculate the color details, the NIQE scale was adopted. To determine the efficiency of the suggested algorithm, it was compared with several algorithms (Abraham et al. [11], Hashim et al. [8], Gupta& Agrawal [13], Daway et al. [9], Ren et al. [12], Abraham et al. [8]. Table 1 shows the evaluation of the enhancement using reference and non-reference quality measurements, where we observed that the best contrast was mostly from the proposed method, followed by Daway et al. [9] and Hashimet al. [8] methods. As for the NIQE scale, the proposed method succeeded in restoring the color information, as it obtained the best evaluation. To know the efficiency of the improvements for the degree of retrieval of the original information, the PSNR measure was adopted, in which the Gupta & Agrawal [13] method and the proposed method showed the best values, which shows that the suggested approach is successful in restoring lighting data for an image that is very close to the original data. Table 2 illustrates chosen four images from the data (24, 34, 196, and 233 as in shown Fig. 3 with labels a, b, c, and d) as a detailed model for enhancement. Fig. 4 represents image _a by the visual observation, we observed that the improved quality of the suggested method was high. Fig. 5 represents image _b and the histogram in Fig. 6. We observed from the distribution of the histogram that the best distribution rates were for the suggested method, followed by the methods [8, 9]. Fig. 7 represents (image _c) enhanced by all algorithms an area that was expanded to see the effect of the enhancement on the marginal areas. We observed the success of the suggested method to improve the marginal areas.

5. Conclusion

In this paper, the low-light images were enhanced based on the suggested algorithm using DCP and color restoration, and lighting enhancement based on the Lab color space and LOL data was used (450 images). To determine the efficiency of the improvement, the proposed method was compared with many algorithms, and non-reference quality metrics were calculated, such as (EN, AG, and NIQE), which measure the amount of improvement in areas. The edges and the amount of retrieval of color information were calculated, and a reference scale (PSNR) was calculated, which shows the degree of departure from the original lighting evidence in the improvement. Through analyzing the results, the suggested method obtained the best quality measurements, which amounted to reaching EN(7.550), AG(9.978), NIQE(3.499), and PSNR(15.013) values, which indicates its success in improving lighting and retrieving color information better than other algorithms. In the future, the suggested method can be used to enhance retinal images.

Table 1. Average quality assessment for LOL data(485 images)

METHOD	EN	AG	NIQE	PSNR
SUG	7.550	9.978	3.499	15.01
Abraham et al. [11]	5.796	4.004	7.358	9.758
Hashim et al. [8]	6.963	5.052	3.450	14.71
Gupta & Agrwal [13]	6.257	4.436	7.832	16.56
Daway et al. [9]	5.831	12.31	9.274	14.99
Ren et al. [12]	5.523	1.117	5.295	9.763
Abraham et al. [10]	5.796	4.004	7.358	9.758

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

Figure. 3 The images were selected from LOL data

Table 2. The qualities for enhanced image (a,b,c & d)

Method	Image_a				Image_b			
	EN	AG	NIQE	PSNR	EN	AG	NIQE	PSNR
SUG	7.630	7.909	2.994	18.086	7.7199	11.173	3.464	16.098
Abraham et al. [11]	5.253	3.487	7.655	7.425	6.341	3.503	5.304	9.435
Hashim et al. [8]	6.334	3.203	3.134	9.947	7.307	7.404	3.517	13.762
Gupta & Agrwal [13]	5.345	2.006	7.0362	10.664	7.164	7.050	5.934	21.009
Daway et al. [9]	4.905	9.134	8.760	15.278	6.532	11.692	6.266	17.932
Ren et al. [12]	4.599	0.289	6.538	6.537	6.486	2.693	3.637	9.966
Abraham et al. [10]	5.253	3.487	7.655	7.425	6.341	3.503	5.304	9.435
Method	**Image_c**				**Image_d**			
	EN	AG	NIQE	PSNR	EN	AG	NIQE	PSNR
SUG	7.900	11.136	3.081	17.071	7.630	7.909	2.994	18.086
Abraham et al. [11]	6.299	4.624	5.733	9.170	5.253	3.487	7.655	7.425
Hashim et al. [8]	7.439	7.138	3.227	14.555	6.334	3.203	3.134	9.947
Gupta & Agrwal [13]	7.017	6.802	7.329	18.307	5.345	2.006	7.036	10.664
Daway et al. [9]	6.400	13.451	8.128	16.075	4.905	9.134	8.760	15.278
Ren et al. [12]	6.216	2.216	4.368	9.258	4.599	0.289	6.538	6.537
Abraham et al. [10]	6.299	4.624	5.733	9.170	5.253	3.487	7.655	7.425

image_a Sug Abraham et al.[11] Hashim et al.[8],

Gupta& Agrawal [13] Daway et al.[9] Ren et al.[12] Abraham et al[10]

Figure. 4 The image (a) is enhanced by several algorithms

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Figure. 5 The image (b) is enhanced by several algorithms

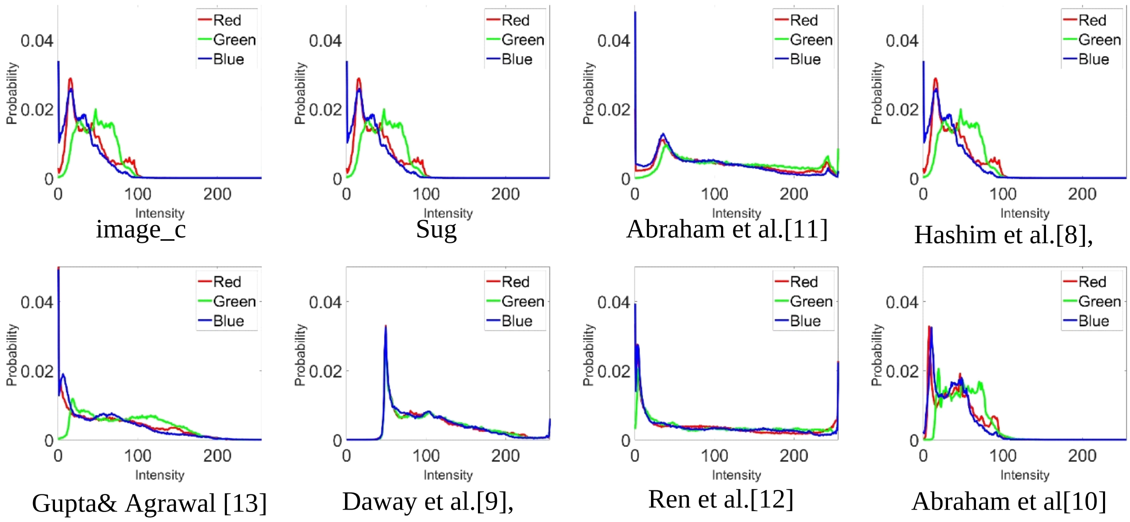

Figure. 6 Histograms of the image (b) enhanced by several algorithms

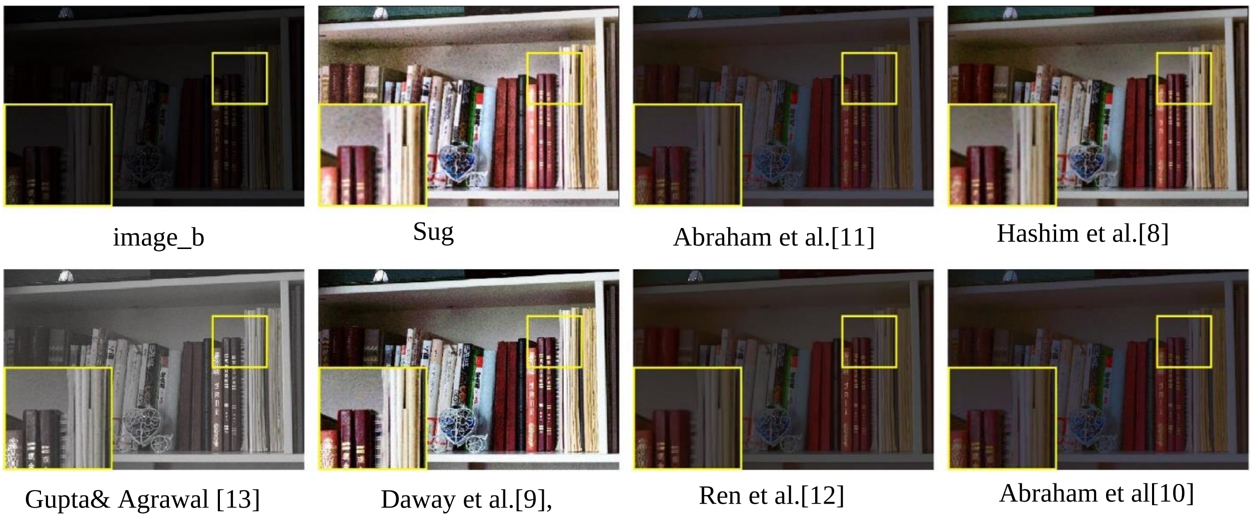

Figure. 7 Comparisons of low lightness image (c) enhancement results with zoom details

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Conflicts of interest

No conflict of interest.

Author contributions

Taqwa Q. kadhim has contributed to the design and implementation of the research by using Matlab. Hazim G. Daway and Ahlam M. Kadhim supervised the written paper and provided the necessary data. All authors approved the final version.

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