An Effective Local Enhancement Approach for Color Images

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Abstract

The main objective of image enhancement is to increase quality and visibility. Since each block of an image has a given luminance, that is local information, a color enhancement method including local contrast enhancement, local sharpness enhancement and local color enhancement is proposed for improving the quality and visibility flow-exposure and high-exposure images. Local information in each block is applied with sliding windows in the proposed method. Simulation results demonstrate that the proposed method is simple and effective for color image enhancement.

Keywords: Gamma correction; Otsu method; luminance enhancement; color enhancement.

1. Introduction

Image enhancement is animportant research area of image processing [1]. Image enhancement technologies are applied in many domains, such as enhancements of natural images, medical images, image recognition, image segmentation, and more.

Image enhancement techniquesare either based onspatial domain or frequency domain analysis. Enhancement techniques based on spatial domain analysis directly process the image pixels.On the other hand, frequency based techniques perform image enhancement using frequency information of the image obtained using some transformation schemes,such asfast Fourier transform(FFT),discrete cosine transform(DCT) and Discrete wavelet transform(DWT). This study proposes aspatial domain based enhancement method.

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There are two common types of contrast enhancement technologies, global enhancement and local enhancement techniques. One advantage of the global contrast enhancement technique is its fast processing speed due to less computational effort. One drawback of global contrast enhancement is that the variance of local information is not considered leading to loss of detailed information. On the other hand, local contrast enhancement utilizes the local information of the image at the expense of more computational effort. This work relies on local contrast enhancement.

Histogram equalization (HE) is a common method for increasing image contrast that is simple and effective. However, the histogram equalization methods suffer from noise and over-enhancements. Several researchers have attempted to improve the traditional histogram equalization method. See for instance the survey of histogram equalization methods in [2]. Methods include brightness preserving bi-histogram equalization (BBHE) [3], dualistic sub image histogram equalization (DSIHE) [4] and minimum mean brightness error bi-histogram equalization (MMBEBHE) [5]. The BBHE scheme divides the original histogram into two histograms using the mean value. After the division, each histogram partition is equalized independently. The DSIHE scheme is similar to the BBHE scheme which divides the histogram according the median rather than the mean. Using the threshold of minimum brightness error MMBEBHE, BBHE and DSIHE decompose an input histogram into two sub histograms. The recursive mean-separate histogram equalization (RMSHE) scheme [6] is an extension of BBHE where the original histogram can be separated into multi-partitions according to the mean. The weighted threshold histogram equalization scheme (WTHE) [7] used two control values to adjust the level of enhancement. Other methods [8-10] have been proposed for resolving the over-enhancement problems. Gamma correction is a well-known method used in both global and local enhancement techniques to increase contrast and luminance of digital images. Although, it is simple and effective in enhancing the image, it requires manual parameter setting. Hence, several studies focus on finding the best gamma parameter settings, including the dynamic range optimization (DRO) method [11], adaptive and integrated neighborhood-dependent approach for nonlinear enhancement (AINDANE) method [12], nonlinear transfer function-based local approach for color image enhancement (NFLACE) method [13] and space-variant luminance map based color image enhancement (SVLMCE) method [14]. DRO is a local gamma correction method that compresses the mean value of the gray level for resolving the low-exposure and high-exposure problem. AINDANE was proposed for color image enhancements including luminance enhancement, contrast enhancement and linear color restoration. NFLACE was derived from AINDANE method; NFLACE uses gamma correction to implement luminance enhancement, and the color hue is preserved by using the HSV color space. SVLMCE developed two gamma correction methods to increase the luminance and enhance the edge sharpness.

This paper is organized as follows. Section II presents the proposed color image enhancement method including the contrast enhancement, sharpness enhancement and color enhancement. Section III displays experimental results. Comparisons between several methods on the basis of the objective and subjective analysis are also provided in Section III. Finally, conclusion is given.

2. The Proposed Method

This section presents a simple and effective color enhancement method including local contrast enhancement, local sharpness enhancement and local color enhancement. The target of the proposed method is to increase the quality and visibility of low-exposure and high-exposure images.

A pixel value of a color image is transformed into a gray level according to Eq. (1):

$$Y(x,y)=0.299\times R(x,y)+0.587\times G(x,y)+0.144\times B(x,y) \quad (1)$$

Where R, G and B are color components; x and y represent the pixel location. The pixel values of image component $R(x, y)$, $G(x, y)$ and $B(x, y)$ are between 0 and 1. Y is an output gray level of an image.

2.1 Local Contrast Enhancement

The proposed local contrast enhancement scheme employs gamma correction. The gamma correction method first transforms the image using the transformation function in Eq. (2).

$$Y' = Y^{\gamma} \quad (2)$$

Where Y' and Y are the gray level output and input images, respectively. The pixel values of images Y' and Y are between 0 and 1. γ is the gamma parameter that is set by the user. Different gamma values would generate different luminance images. Figure 1 shows the gamma correction according to different parameter values.

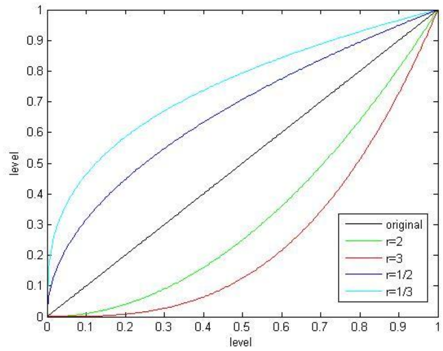


Figure 1: Gamma correction according to difference gamma values

Fig. 1 shows that if the parameter value is close to 0, the luminance is brighter than the input. On the other hand, if the parameter is greater than 1 the luminance of the output becomes darker than the input. However, the parameter is usually set by the user. Thus, an automatic gamma parameter determination mechanism is used.

The auto-determination gamma parameter method was initially designed for the global contrast enhancement algorithm. Each block of the image has its luminance contrast enhanced using a overlapping mechanism [1]. The formulas are shown in Eqs. (3) and (4):

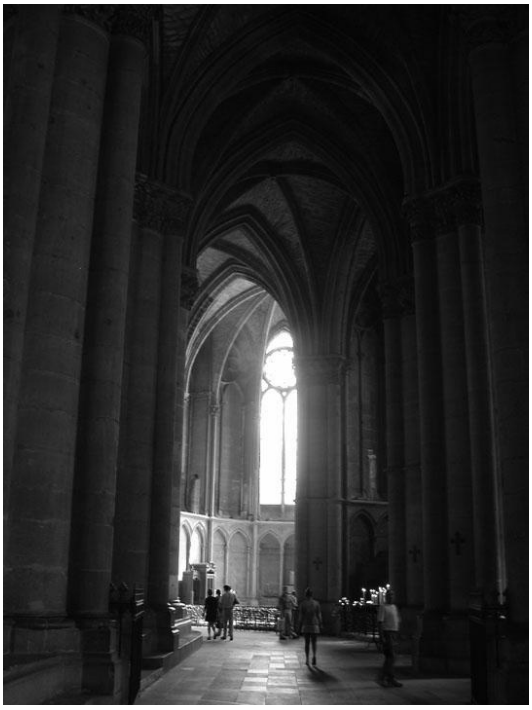
$$E = Y_{cb}^{\gamma} \quad (3)$$

$$\gamma=\log_2\left(2+\frac{((iMean-iOT)+(iMean-0.5)+(iOt-0.5))}{2}\right) \quad (4)$$

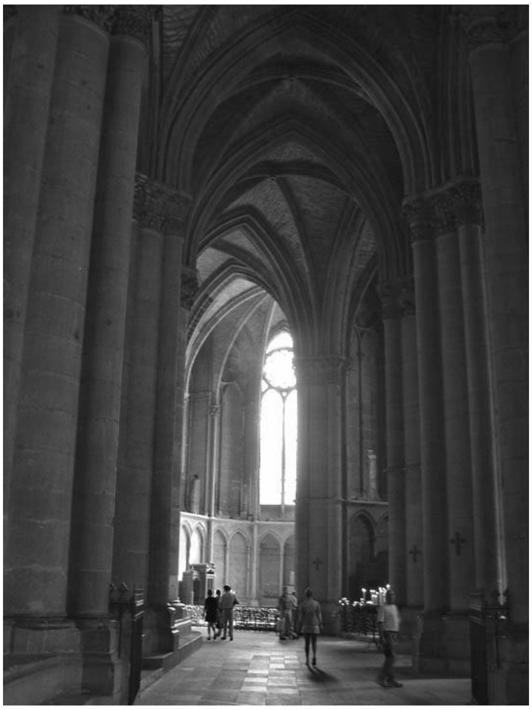
Where Y_{cb} is the shifted gray level block of the input image Y. E is an output image resulting from the local contrast enhancement. The gamma parameter is estimated by using the mean of image and the Otsu threshold. The *iMean* is the mean of the input image, *iOT* is the Otsu threshold calculated by the Otsu method [11]. The original Otsu method separated the input image into foreground and background images. This study separates the input image into dark and bright images. The first term of the numerator represents the gain factor that increases or degrades the luminance. The second and third terms expect the dynamic range of grey levels to be compressed to yield better result.

$$\gamma = \log_2(2 + \frac{((iMean - iOT) + (iMean - 0.5) + (iOt - 0.5))}{2}) \quad (5)$$

Figure 2 shows the result of using the local contrast enhancement method.



(a)



(b)

Figure 2: (a) original image (b) image with local contrast enhancements

2.2 Local Sharpness Enhancement

The main objective of the sharpness enhancement is to increase details and enhance veined pattern or the edge, but too much sharpness enhancement increases the noise in the resulting image. Hence, a simple local sharpness enhancement algorithm is proposed to reduce the noise. Equation (6) displays the local sharpness enhancement function:

$$S(x,y) = E(x,y) - (E_{b\_std} - (E(x,y) - E_{b\_mean})) \quad (6)$$

Where $S(x,y)$ and $E(x,y)$ are the output image and input image after using the local sharpness enhancement and local contrast enhancements, respectively. E_{b_std} and E_{b_mean} are the standard deviation and mean of E in the shifted mask respectively.

2.3 Local Color Enhancement

In this section, a simple color enhancement scheme is proposed based on color weights. The color weights are calculated according to Eq. (7):

$$\begin{cases} \omega_r = 0.5774 \times \frac{Y}{R} \\ \omega_g = 0.5774 \times \frac{Y}{G} \\ \omega_b = 0.5774 \times \frac{Y}{B} \end{cases} \quad (7)$$

Where *R*, *G*, and *B* are components of an RGB color image, *Y* is a gray level image that is calculated using Eq. (1), ω_r, ω_g and ω_b are the color weights for the RGB color image. Tigure 4 shows the relationship between the RGB color and the gray level in the RGB color model [1].

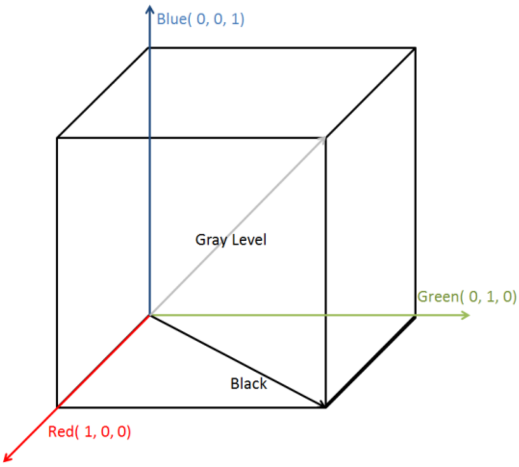


Figure 4: RGB color model

The RGB pixel values in Fig. 4 are between 0 and 1. The range of the dark can be calculated and then gray level region can be obtained. Thus, the ratio of gray level and RGB color is $\sqrt{3}$ *i.e.*, 0.5774. After calculating the color weight ω, the color enhancement is then implemented using Eq. (8).

$$\begin{cases} R'(x,y) = \dfrac{0.5774 \times I'(x,y)}{\omega_r(x,y)} \\ G'(x,y) = \dfrac{0.5774 \times I'(x,y)}{\omega_g(x,y)} \\ B'(x,y) = \dfrac{0.5774 \times I(x,y)'}{\omega_b(x,y)} \end{cases} \quad (8)$$

Where $I'(x,y)$ represents the enhanced image. $R'(x,y)$, $G'(x,y)$ and $B'(x,y)$ are the enhanced color component of the output image.

3. Experimental Results

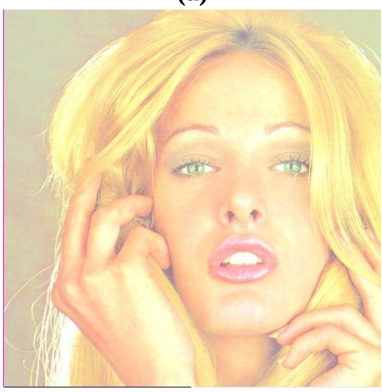
In our experiment, the contrast enhancement method is set by using the 45×45 overlapping window sizes and shifted 5 pixels at a time along the row. After sliding along the row, it shifted along the column the same number of pixels. The local sharpness enhancement is calculated by 3×3 pixel mask.

We compared several algorithms using both objective and subjective analysis. These included the traditional gamma correction (GC), commonly histogram equalization (HE), DRO, WTHE and SVLMCE. And three types of test images were simulated. These three types of test images include low-exposure, high-exposure and normal exposure images.

The images used in the simulations (see Figs. 6-8) are form the Kodak signal and image processing institute (SIPI) and NASA respectively. The subjective analysis results are shown in Figs. 6-8.

Figure 6(a) shows a high-exposure image. In Figure 6(b) a fixed gamma parameter (γ=0.5) is used that caused luminance to be over-enhanced. Figure 6(c), displays the output image of applying HE. Figure 6(d) shows the normal contrast image after applying WTHE, but the result looks unnatural. The image subject to DRO is shown in Figure 6(e) which gives a high-exposure result. The result of applying SVLMCE is demonstrated in Figure 6(f) with increased luminance and reduced contrast. The image resulting from the proposed method is displayed in Figure 6(g); the proposed method is able to successfully reduce the luminance of high-exposure image and increase the contrast of the image.

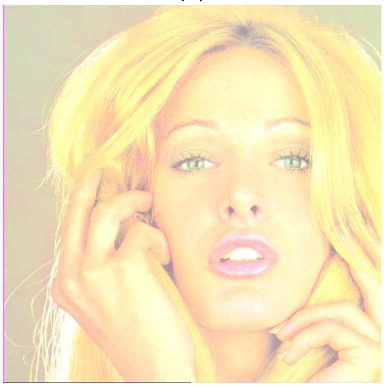
(a)



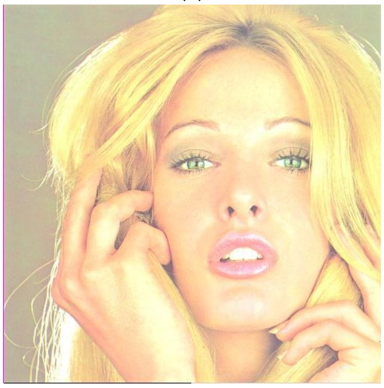
(b)

(c)

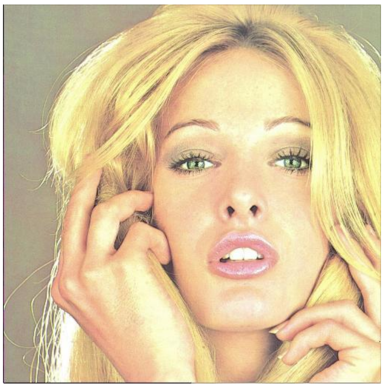
(d)



(e)



(f)



(g)

Figure 6: (a) Original (b) GC(γ=0.5) (c) HE (d) WTHE (e) DRO (f) SVLMCE (g) Proposed method

Figure 7(a) shows another original image. Figure 7(b) shows the high-exposure results after applying a fixed gamma parameter (γ=0.5). Figure 7(c) shows the over-enhanced results obtained with HE. The high-exposure image caused by WTHE is shown in the Figure 7(d). This image has lost its details and contrast. DRO achieves suitable contrast in the rabbit, but the underbrush looks unnatural (see Figure 7(e)). Figure 7(f) looks similar to the input image indicating that SVLMCE did not increase the contrast and detail. Figure 6(g) shows the results of the proposed method where image luminance is reduced and the contrast is enhanced (see Figure 7(g)).

(a)

(b)

(c)

(d)

(e)

(f)

(g)

Figure 7: (a) Original (b) GC(γ =0.5) (c) HE (d) WTHE (e) DRO (f) SVLMCE (g) Proposed method

Figures 8(b), (c) and (d) show that high-exposure luminance is increased and the contrast of text is reduced on the hats. Figures 8(c) and (d) show the resulting images after applying HE and WTHE, respectively. These images are over-enhanced, hence the sky is dark. The proposed method yielded better result compared to the other methods and the contrast of the text on the hats is enhanced (see Figure 8(g)).

(a)

(b)

(c)

(d)

(e)

(f)

(g)

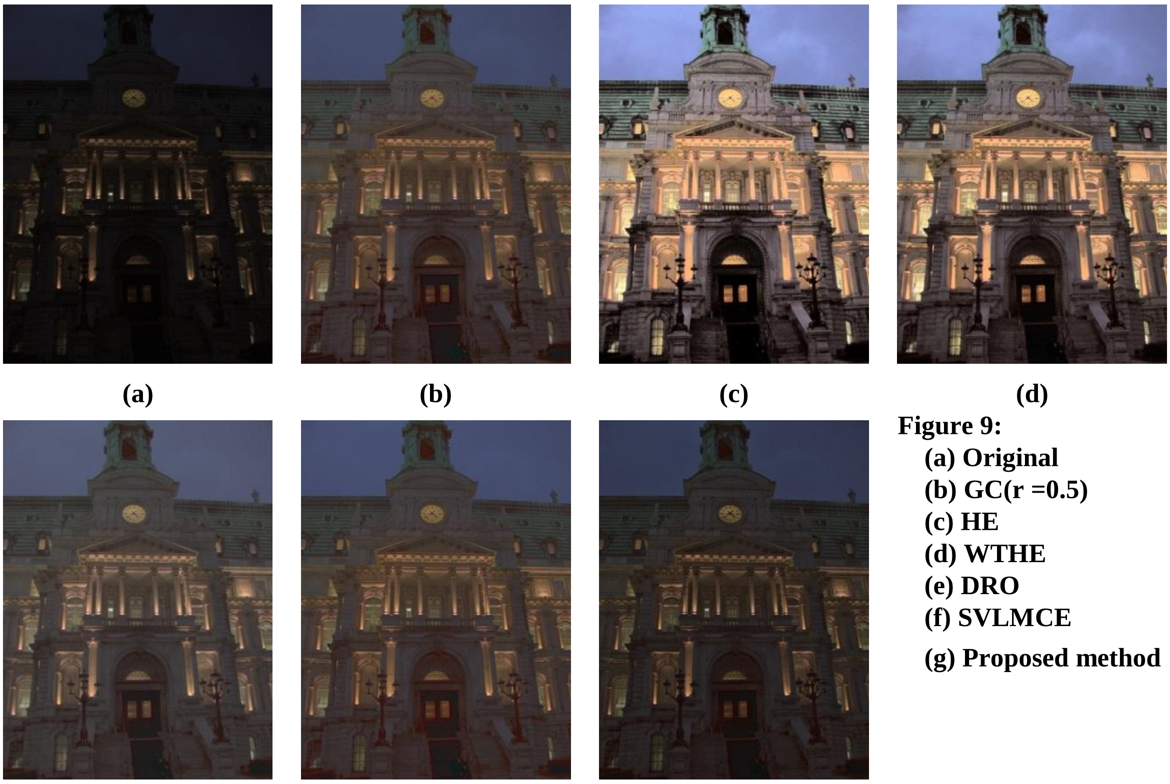
Figure 8: (a) Original (b)GC(r =0.5) (c)HE (d)WTHE (e)DRO (f) SVLMCE (g) Proposed method

A low-exposure image test is shown in Figure 9. Figures 9(b), (e) and (f) demonstrate successful luminance increases, but the color of the pillar is chromatised. Figures 9(c) and (d), shows that the resulting images after applying HE and WTHE becomes over-enhanced. The best result is obtained using the proposed method.

Meanwhile, Table 1 shows the objective analysis by comparing structural similarity (SSIM) on three types of images. The SSIM is commonly used to measure the similarity between images. The SSIM value is in the range of 0~1. A high SSIM value signals high similarity. According to Table 1, the suggested method yielded the highest SSIM value as compared with the other schemes. The proposed method thus produces better results.

Table 1 ASSIM measure from three test image

Method	*SSIM*
GC	0.74
HE	0.51
WTHE	0.66
DRO	0.70
SVLMCE	0.79
Proposed	0.83



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

(e) (f) (g)

Figure 9:
(a) Original
(b) GC(r =0.5)
(c) HE
(d) WTHE
(e) DRO
(f) SVLMCE
(g) Proposed method

4. Conclusion

A simple and effective color enhancement method is proposed. The proposed scheme employs local contrast enhancement, local sharpness enhancement and local color enhancement by applying local information to improve quality and visibility for low-exposure and high-exposure images. Simulation results, indicates that the proposed method performs better than the other methods.

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