Low-Illuminated Image Enhancement Using Power Law Transformation and Image Fusion

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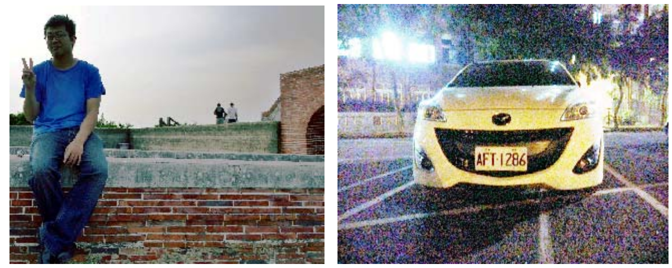
***Abstract*-In this paper, a low-illuminated image enhancement method is studied by using power law transformation (PLT) and image fusion. First, the PLT is used to enhance image. However, the exponent of PLT is difficult to be chosen such that all objects on image have good enhanced qualities. So, an image fusion method is then presented to combine the PLT enhanced images with various exponents to obtain the final image. In the experiments, the backlighting and nighttime images are used to demonstrate the effectiveness of the proposed method.**

I. INTRODUCTION

In our daily life, it is often to capture image in backlighting and nighttime situation by using camera. In these cases, the captured images are low-illuminated and very dark, as shown in Fig.1. The objects on the images have low contrast and poor quality. Therefore, it is desirable for us to develop an image enhancement method to improve the image quality and contrast. In the literature, several methods have been presented to solve this problem. In [1], the histogram equalization method spreads the histogram of image intensity uniformly to get enhanced results. In [2], the homomorphic filtering approach uses the illumination-reflectance model to perform the high-pass filtering in the log domain. In [3], the detail-enhanced multi-scale exposure fusion method merges differently exposed low dynamic range images to enhance image. Fig.2 shows the enhanced results of the two low-illuminated images in Fig.1 by using histogram equalization method. It is clear that the color qualities do not look good enough although the brightness of image have been improved. Therefore, a new enhancement method needs to be developed. In this paper, a low-illuminated image enhancement method is presented by using power law transformation and image fusion. Several low-illuminated images will be used to evaluate the performance of the proposed method.

(a) (b)

Fig.1 Two low-illuminated images in our daily life. (a) A backlighting image. (b) A nighttime image.



(a) (b)

Fig.2 Enhanced results using histogram equalization. (a) Enhanced backlighting image. (b) Enhanced nighttime image.

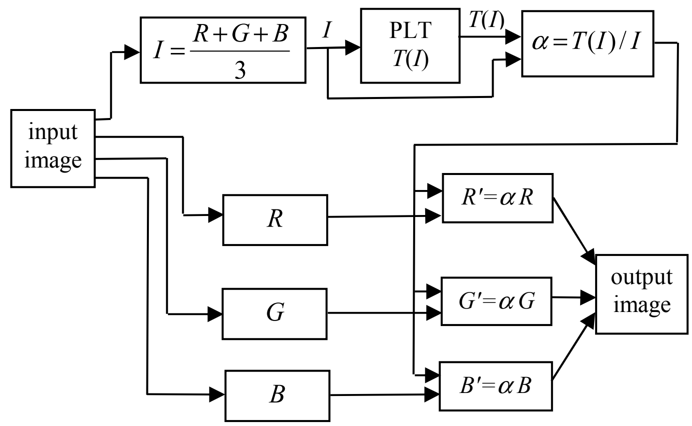


Fig.3 A color image enhancement method based on power law transformation (PLT).

II. IMAGE ENHANCEMENT USING PLT

In this section, a low-illuminated digital image enhancement method based on power law transformation (PLT) is presented. The block diagram is shown in Fig.3 whose step-by-step procedure is described below:

Step 1: For each color pixel (R,G,B), its intensity I is computed by

$$I = \frac{R + G + B}{3} \tag{1}$$

where R, G, B and I all have 8-bits representation so their values are in the interval [0,255].

Step 2: Use the following power law transformation to compute the transform intensity $T(I)$ below:

$$\begin{aligned} T(I) &= 256\left(\frac{I}{256}\right)^{p} \\ &= I^{p}(256)^{1-p} \end{aligned} \tag{2}$$

where exponent p is a prescribed positive real number. If $p = \frac{1}{2}$ is chosen, then we have $T(I) = 16\sqrt{I}$. It can be observed that if $p < 1$ is selected, the under-exposed image is amplified. If $p > 1$ is chosen, the over-exposed image is shrunk. If $p = 1$ is chosen, the image is not changed.

Step 3: Compute the scaling factor α by the equation

$$\alpha = \frac{T(I)}{I} \qquad (3)$$

Step 4: The color pixel (R',G',B') of the enhanced image is then given by

$$R' = \alpha R \; , \quad G' = \alpha G \; , \quad B' = \alpha B \qquad (4)$$

Because color pixel (R,G,B) is multiplied by the same factor α, the hue and saturation of color image are not changed. Only intensity of pixel is amplified by α to enhance image.

Now, one numerical example is used to evaluate the performance of the above PLT method. Fig.4 shows the enhanced results of backlighting image in Fig.1 with exponents $p = \frac{1}{2}$ and $p = \frac{1}{3}$. From these two results, it is clear that the exponent of PLT is not easy to be selected such that all objects on image have good enhanced qualities. So, an image fusion method needs to be developed to combine the PLT enhanced images with various exponents. The details will be described in next section.

(a) (b)

Fig.4 Enhanced results using the power law transformation. (a) Result with $p = \frac{1}{2}$. (b) Result with $p = \frac{1}{3}$.

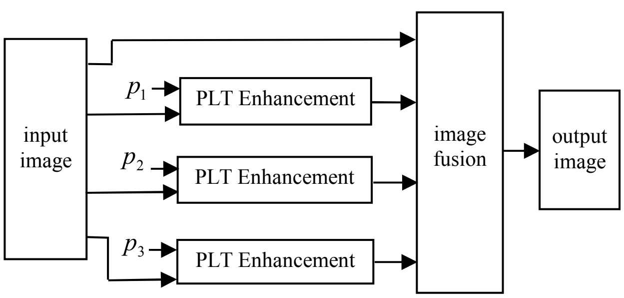


Fig.5 The block diagram of image fusion method with $L = 3$.

III. IMAGE FUSION AND EXAMPLES

In this section, an image fusion method is first presented. Then, numerical examples are illustrated. The image fusion method combines the PLT enhanced images with various exponents p_ℓ ($\ell = 1,2,\cdots,L$) to obtain final enhanced result. The block diagram of proposed image fusion method with $L = 3$ is shown in Fig.5. If $c_0(m,n)$ is the given original image and $c_\ell(m,n)$ for $\ell = 1,2,\cdots,L$ are the enhanced PLT images gotten by exponents p_ℓ, then the fused image can be computed by

$$\hat{c}(m,n) = \sum_{\ell=0}^{L} \frac{W(I_\ell(m,n))c_\ell(m,n)}{W(I_\ell(m,n))} \qquad (5)$$

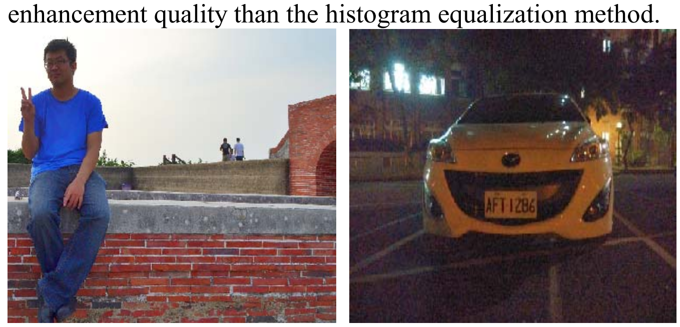
where $I_\ell(m,n)$ are the brightness or intensities of the enhanced color images $c_\ell(m,n)$. The weighting functions can be chosen as one of the following three functions whose definitions are given by:

Gaussian: $$W(I_\ell(m,n)) = \exp\left(\frac{-1}{2}\left(\frac{I_\ell(m,n)-128}{128}\right)^2\right) \qquad (6a)$$

Parabolic: $$W(I_\ell(m,n)) = \frac{I_\ell(m,n)(256-I_\ell(m,n))}{128^2} + 0.1 \qquad (6b)$$

Sine: $$W(I_\ell(m,n)) = \sin\left(\frac{I_\ell(m,n)}{256}\pi\right) + 0.1 \qquad (6c)$$

Because each weighting function has its unique feature, we can choose a preferred one to enhance image. Now, a numerical example is illustrated. The enhanced results of the backlighting and nighttime images in Fig.1 are studied here. The $L = 3$ and Gaussian weighting function are selected. Moreover, the exponents of PLT are chosen as $p_1 = \frac{1}{2}$, $p_2 = \frac{1}{3}$, $p_3 = \frac{1}{4}$. Fig.6 shows the enhanced images using proposed fusion method. After comparing the results in Fig.2 and Fig.6, it can be observed that the enhanced results in Fig.6 looks better than those in Fig.2, so the proposed method provides better color enhancement quality than the histogram equalization method.



(a) (b)

Fig.6 Enhanced results using proposed fusion method. (a) Enhanced backlighting image. (b) Enhanced nighttime image.

IV. CONCLUSIONS

In this paper, a low-illuminated color image enhancement method has been studied by using PLT and image fusion. However, only the PLT method is considered here. Therefore, the topic that combines various image enhancement methods using image fusion may be investigated in the future.

REFERENCES

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