Contrast Enhancement of Low-light Image Using Histogram Equalization and Illumination Adjustment

Partha Pratim Banik, Rappy Saha, and Ki-Doo Kim*
School of Electrical Engineering, Kookmin University, Seoul, Korea
*ppbanik006@kookmin.ac.kr, rappysaha@kookmin.ac.kr, kdk@kookmin.ac.kr**

Abstract

Low-light image contains compressed dynamic range that can be enhanced for knowing detail information. Contrast enhancement of low-light image is a challenging task in image processing field. In this paper, we enhance the different type of low-light image by using histogram equalization (HE) and illumination adjustment. We present a method to detect different types of low-light images. Then, we apply the HE on V channel of input low-light image after converting the color space from RGB to HSV. After that, we enhance the contrast of V by adjusting intensity (V) of low-light image with adopting gamma correction. We evaluate our low-light enhanced method by naturalness image quality evaluator (NIQE) and colorfulness-based patch-based contrast quality index (CPCQI) and also compare our proposed method with typical HE method by measuring quality of images.

Keywords: low-light Image, Illumination adjustment, HE, NIQE, CPCQI

1. Introduction

Low-light condition is responsible to lose the detail information of any surface. The enhancement of low–light image sometimes causes to enhance the noise in dark region. As a result, only enhancement of low-light image cannot preserve the good contrast. The loss of contrast causes human perceptual visibility problem. To overcome this problem, we need to enhance the contrast of different low-light images to extract the detail of the input image.

Low-light is caused by different reasons. It can be occurred from insufficient source of light, shadow of object, under low luminance strong light weakening [1] etc. Feng et al. presented an enhancement method via dark channel by improving the contrast of low luminance strong light weakening images [1]. Park et al. enhanced the visibility of strong low light image and also reduced the noise using non-local means (NLM) denoising step. They effectively reduced the high intensity noise by tone mapping approach for enhancing the visibility [2]. Yue et al. proposed a decomposition method that decomposed an image into reflectance and illumination layer and they enhanced the illumination layer by adjusting illumination with gamma correction suppressing noise with revised popular BM3D noise to enhance different kinds of low illumination images [3, 4]. Their method is quite slow and it takes long time, about 12 seconds to process [3]. We follow their illumination adjustment method and apply it after histogram equalization (HE). We also introduce a method to detect different types of low-light image based on HE.

In this paper, we discuss our method in section II, and also discuss about the result and evaluation of our method in section III. We conclude in section IV.

2. Proposed Method

At first, we convert the color space from RGB to HSV (Hue Saturation Value). Then, we convert the V channel by HE method. After that, we compare histogram equalized V channel with actual V channel and measure the maximum intensity of V channel from this comparison. We define some condition and threshold based on the analysis of histogram of different kinds of low-light image for detecting the type of low-light image. Rather than, we adjust the illumination by the help of gamma correction from [3] and we apply this adjustment to histogram equalized V channel or actual V channel of HSV color space based on the defined condition. And finally, we convert the HSV color space to RGB color space to get the enhanced image. The block diagram of the proposed method is shown in Fig. 1.

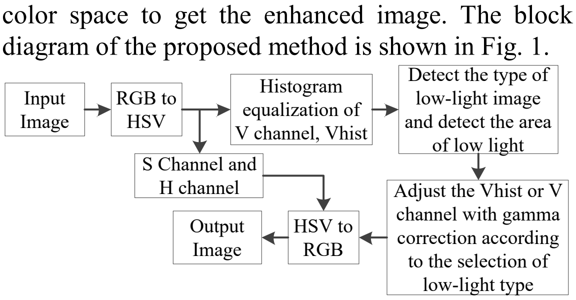

Figure 1. Block diagram of proposed method.

A. HE of V Channel

First, we convert input image from RGB color space to HSV color space. We apply HE algorithm to V channel [5]. The equation for HE is shown in (1).

$$S_k = 255\sum_{j=0}^{k}\frac{n_j}{n}, k = 0,1,2,......,255 \quad (1)$$

$$V_{hist}(x, y) \in S_k \quad (2)$$

In (1), S_k is the histogram equalized intensity value of V channel, n_j is the number of pixels in jth intensity of V channel and n is the number of total pixels and $V_{hist}(x, y)$ has the matrix form of histogram equalized intensity of V channel.

B. Detection Type of Low-light

In this stage, we compare the value of $V_{hist}(x, y)$ with $V(x, y)$ and then measure the maximum value of the comparison matrix.

$$V_{comp}(x, y) = (V_{hist}(x, y) < V(x, y)) \times V(x, y) \quad (3)$$

$$V_{compMax} = \max(V_{comp}(x, y))/255 \quad (4)$$

In (3), $V_{comp}(x, y)$ contains the values of $V(x, y)$ which are greater than $V_{hist}(x, y)$. Here, the operator '$\times$'means element wise multiplication. In (4), $V_{compMax}$ is the max normalized value of $V_{comp}(x, y)$.

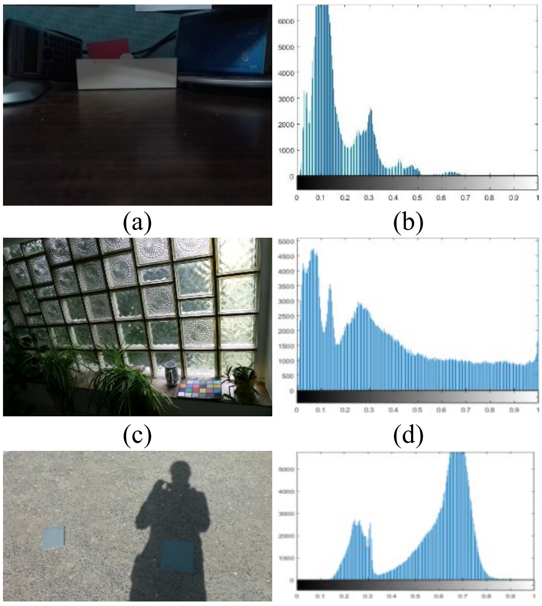

Figure 2. (a), (b) Strong low-light image and corresponding histogram, respectively, (c), (d) medium low-light image and corresponding histogram, respectively, and (e), (f) low-light due to shadow and corresponding histogram, respectively.

In Fig. 2, we can see three different level low-light images. Fig. 2 (a), (b) show strong low-light image and corresponding histogram, respectively. From the histogram of Fig. 2(a), we can see that most of the pixels are distributed between 0 to 0.5. Fig. 2 (c), (d) show medium low-light image and corresponding histogram, respectively. Fig 2(d) shows that this type of low-light image has maximum pixel distribution from 0 to 0.6. Fig. 2(e) shows the shadow effect low-light condition and the corresponding histogram of Fig. 2(e) shows the maximum pixel distribution 0.4 to 0.8 in Fig. 2(f). So, we can define some conditions based on these different kind of low-light image histogram analysis. We will execute some operations inside the conditions. So we need to introduce these operations before conditions. It is important to note that the x axis of histogram of Fig 2(b), (d), and (f) are normalized value range from 0 to 1.

$$V_{llp}(x, y) = (V_1(x, y)/255 \le th) \times V_2(x, y) \quad (5)$$

$$V_{op}(x, y) = (V_1(x, y)/255 \ge th) \times V_2(x, y) \quad (6)$$

$$V_{llp,updated}(x, y) = 255 \times (V_{llp}(x, y)/255)^{(1/\gamma)} \quad (7)$$

$$V_{enh}(x, y) = V_{llp,updated}(x, y) + V_{op}(x, y) \quad (8)$$

In (5) and (6), $V_{llp}(x, y)$ and $V_{op}(x, y)$ is the low-light pixel intensity and low-light free pixel intensity at (x, y) position, respectively and th is the threshold value which is decided from the conditions. $V_1(x, y)$ and $V_2(x, y)$ are two different intensity matrix which are either $V_{hist}(x, y)$ or $V(x, y)$ and they depend on the conditions. In (7), $V_{llp,updated}(x, y)$ is the updated low-light intensity which was introduced in [3] and γ is gamma value. Equation (7) is called the gamma correction [3]. In (8), $V_{enh}(x, y)$ is the final enhanced intensity value at (x, y) position which is measured by adding $V_{llp,updated}(x, y)$ and $V_{op}(x, y)$. Now the conditions are given following:

$$0.1 < V_{compMax} < 0.6\,,$$
$$th = 0.6\,;\; V_1(x, y) = V(x, y)\,; \quad (9)$$
$$V_2(x, y) = V_{hist}(x, y) \text{ in (5), (6)}$$

$$0.6 < V_{compMax} < 1\,,$$
$$th = 1\,;\; V_1(x, y) = V(x, y)\,; \quad (10)$$
$$V_2(x, y) = V_{hist}(x, y) \text{ in (5), (6)}$$

$$\begin{cases} 0 < V_{compMax} < 0.1, th = 1; \\ V_1(x, y) = V_2(x, y) = V_{hist}(x, y) \\ otherwise, th = 1; V_1(x, y) = V_2(x, y) = V(x, y) \end{cases} \quad (11)$$
$$\text{in (5), (6)}$$

(9) is for detecting medium low-light image and the th is set to 0.6 because maximum pixel

distribution of medium low-light image ranges up to 0.6 and γ is 3. (10) detects the low light area in high illumination, γ is 2.2 and (11) detects strong low-light areas that are almost dark and γ is 1.6.

C. Convert HSV to RGB Color Space

The $V_{enh}(x, y)$ is placed to V channel of HSV color space. The Hue and saturation channel remains unchanged. So, we can avoid color dissimilarity. After converting the HSV to RGB color space we can get the enhanced output.

3. Result and Discussion

In this section, we will show three images, one is in strong low-light image, other is in medium low-light image and the last one is in partially low-light

Table 1: Quality Value List by NIQE and CPCQI Metric for HE and Our Proposed Method

Images	HE Method		Proposed Method	
	NIQE	*CPCQI*	*NIQE*	*CPCQI*
Table	2.74	0.60	1.90	0.84
Memorial	3.41	0.61	2.06	0.74
House Side	3.03	0.58	2.57	0.75

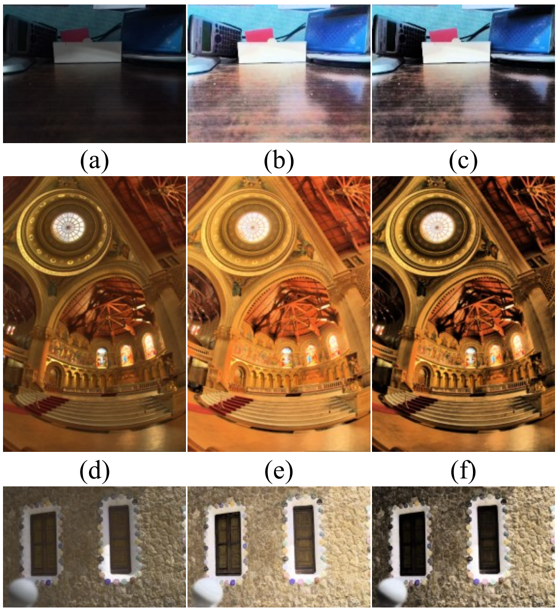

Figure 3. (a) Strong low-light image *Table*, (b) enhanced *Table* image by our method, (c) enhanced *Table* image by HE method, (d) medium low-light image *Memorial*, (e) enhanced *Memorial* image by our method, (f) enhanced *Memorial* image by HF method, (g) partially low-light image *House Side*, (h) enhanced *House Side* image by our method and (i) enhanced *House Side* image by HF method.

image. We also measure the quality of image with our method and HE method by naturalness image quality evaluator (NIQE) [6] and colorfulness-based patch-based contrast quality index (CPCQI) [7] non-reference image quality assessment metric and we list the quality value of these two methods in Table 1. The larger NIQE value represents lower quality of image and the larger CPCQI value represents higher quality of image. From Fig. 3(b), we see that the strong low light image is enhanced and the 'calculator' object is easily visible where this object is not so clear in Fig. 3(a). On the other hand, in Fig. 3(c), the 'calculator' object is detected but not so much exposed as shown in Fig. 3(b). Now in Fig. 3(d), the 'roof' of Memorial is quite dark which is much more exposed in Fig. 3(e) but not so much exposed in Fig. 3(f) and it is being quite darker. In Fig. 3(g), a 'shadow' is noticed although the image is in proper illumination. In Fig. 3(h), it is removed mostly and the 'windows' become more clear than Fig. 3(g) and 3(i). So, all together it can be said that the proposed method can reveal the low-light part very effectively. Moreover, from table 1, we can also see that the NIQE quality value is lower than the quality value of HE method and CPCQI quality value for our proposed method is larger than HE method.

4. Conclusion

In this paper, we detect not only the area of the low-light of the image but also distinguish the three kinds of low-light images that makes the algorithm efficient. In some cases, when we are going to enhance much more to the very weekly dark area, it amplifies an unexpected noise that instantly reduces the contrast and visibility characteristics of the image. We apply HE in V channel which helps us to detect not only the low light area but also helps to enhance the image. It is useful to detect low-light area by applying HE because after applying HE, the stronger dark area of normally exposed low-light image become more darker. As a result, the dark parts of histogram equalized image become less value than the dark part of input normally exposed low-light image. But the HE of strong low-light image which is captured in dark room or night time increases the artifact into the image and all pixels become larger than input strong low-light image pixel. This phenomenon also helps to detect the strong low-light image. Thus the method is very helpful to detect the category of low-light image and also useful to enhance the image. The adopting correct value of gamma will be more helpful to enhance any kind of low-light image, but in this paper, we approximate the value of gamma for different kind of low-light image experimentally. In the future, we will find the better way to calculate the optimal value of gamma for different kind of low-light image.

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