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Enhancing Dark Images Captured On Camera

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Abstract. In recent years, dark image enhancement technology has emerged as a popular subject of research, and has played an important role in security monitoring, traffic management, military reconnaissance, and film production. To solve the problems posed by images captured in poor lighting such that the target is not visible or is difficult to read, we propose a method to process such images to identify the targets in them. An algorithm is developed that uses the dynamic threshold method to determine the white reference point in the image as well as the brightest ten percent of pixels according to size. It then adjusts the white point and balances the area to obtain the final result. Using this, the gamma transform is used to adjust the brightness of the image. The results of experiments show that the proposed method can enhance image brightness without loss of color in the image to preserve its naturalness and improve object recognition in natural scenes.

1. Introduction

Dark images are common, and are characterized by low lighting. Such images alter the original image to some extent, which is inconvenient for observation and analysis, and has a negative impact on applications such as image matching, fusion, analysis, detection, and segmentation [1, 2].

Current research has focused on image enhancement for low-contrast or low-light images, and little attention has been devoted to dark images. Methods for the enhancement of dark images can be roughly divided into traditional methods and deep learning methods.

Deep learning is the most common approach to image enhancement based on Artificial Intelligence, but its major problem is the requirement of a large dataset. It also has weak generalization ability and other limitations [3].

Traditional methods are widely used in image contrast enhancement, including automatic color enhancement (ACE) [4], histogram equalization (HE) [5], Retinex [6], contrast-limited adaptive histogram equalization (CLAHE) [7], gamma correction [8], and other methods[9,10] to improve image brightness.

Research on enhancing dark images is still exploratory. Although some advances have been made, the field is far from mature, and thus has significant research value and space for development [2].

2. Related work

The ACE[11] can "adapt" to widely varying lighting conditions to effectively extract visual information from the environment. It has been shown to achieve effective color constant correction and satisfactory tone equalization while performing global and partial image correction.

The HE enhances the overall contrast of the image by extending the dynamic range of the gray values of pixels, but it can distort contour details and is plagued by other spurious phenomena after processing. It is mainly used for images in which the gray value of pixels is concentrated in a narrow

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region or a range of low luminance, whereas the distribution of histograms of images processed in this paper is concentrated around zero [5].

The CLAHE algorithm differs from ordinary histogram equalization in contrast clipping so that the image contrast it provides is more natural. The advantage of this algorithm is that it does not ignore parts that are beyond the limit, but distributes cropped parts evenly to the other parts of the histogram, as shown in figure 1.

Retinex theory assumes that the illumination gradually changes in space [12]. This assumption deviates from practice, and the proportion of the three channels of the image is identical by default, which causes the processed image to be dark and noisy [13]. We thus use a real-time MSR method for comparative testing.



Figure 1. CLAHE.

3. Our method

Our method aims to improve image contrast. Its main benefits are color correction and brightness enhancement.

AWB is an important feature of digital cameras. The goal of the white balance is to adjust the image to make it appears as if it had been shot under normal light.

The algorithm uses dynamic thresholds for white point detection, and is more flexible than the adhoc algorithm [14].

The AWB method consists of two steps: white point detection and white point adjustment. The process is as below.

3.1. White point detection

To render the processing of chromaticity and brightness mutually unaffected, we convert the image from RGB to YCbCr color space. To enhance the robustness of the algorithm, the image is divided into 12 parts with an aspect ratio of 4:3, because many digital photos satisfy this ratio. The pictures used in this paper were taken by a digital camera, which rendered the enhancement more targeted.

We use dynamic thresholds to detect white points in an image. We first calculate the mean and sum of C_b and C_r , respectively, and then the average absolute differences D_b and D_r .

^b and ^r, respectively, and then the average absolute differences ^b and ^r. $\sum_{r=1}^{n} \sum_{r=1}^{n} d_{r} d_{r} d_{r} d_{r}$

$$D_{b} = \sum_{i,j} (|C_{b}(i,j) - M_{b}|) / N$$
(1)

$$D_{r} = \sum_{i,j} \left(\left| C_{r}(i,j) - M_{r} \right| \right) / N$$
(2)

where $C_b(i, j)$ and $C_r(i, j)$ are the chrominance values of pixels (i, j), and N is the number of pixels used in the calculation. If the D_b and D_r values of the region are too small, the region is discarded because it does not have sufficient color change, indicating that the color distribution of this block is relatively uniform. Such locality influence the white balance. The final M_b , M_r , D_b and D_r are obtained by averaging the areas of the blocks.

Furthermore, we initially determine the white area that satisfies the following formulae:

$$\left|C_{b}(i,j) - (M_{b} + D_{b} \times sign(M_{b}))\right| < 1.5 \times D_{b}$$
(3)

$$\left|C_{r}(i,j) - (1.5 \times M_{r} + D_{r} \times \operatorname{sign}(M_{r}))\right| < 1.5 \times D_{r}$$

$$\tag{4}$$

Based on the luminance values, we select the top 10 candidate reference white points in the white region as reference white points. The white area is a set (C_r, C_b) whose corresponding pixels satisfy the above formulae.

3.2. White point adjustment

To maintain the brightness of the entire image at the same level, we calculate the average values R_{avew} , G_{avew} , B_{avew} of the white reference point for each channel, and the maximum luminance value was used to derive the channel gain:

$$R_{gain} = Y_{max} / R_{avew} \tag{5}$$

$$G_{gain} = Y_{max} / G_{avew} \tag{6}$$

$$B_{gain} = Y_{max} / B_{avew} \tag{7}$$

Based on the Von Kries diagonal model, we make the following adjustments to the values of each pixel in the image:

$$R' = R \times R_{eain} \tag{8}$$

$$G' = G \times G_{gain} \tag{9}$$

$$B' = B \times B_{gain} \tag{10}$$

where R, G and B are the original values of the pixels in the image, and R', G' and B' are their respectively adjusted pixel values.

The human eye's sensitivity to external sources of light is not linear with light intensity, but is exponential. The camera's sensitivity is linear, however. To enable the human eye to recognize the contents of images, it is necessary to perform gamma correction [8] on the image captured by the camera. Research has shown that the gamma correction method is significantly better than other methods when the gamma value is 0.7.

4. Experiments

4.1. Color Balance

We used AWB and ACE to restore image color and compared them. The effect is shown in figure 2. The AWB algorithm clearly yields more natural results.



(d)Image II (e) ACE (f) AWB Figure 2. Comparison of ACE and AWB.

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Figure 4. Comparison of related methods and our method.

4.2. Brightness Enhancement

We tested different methods on night vision images, including the HE, CLAHE, MSR, and gamma correction. We also compared the effects of processing different color spaces in the HE and CLAHE algorithms. The results show that the exhibited different phenomena of color deviation and unclear colors in HSV and YUV. The effect of gamma correction was clearly more natural, and is shown in figure 3. Further verification results can be seen in figure 4.



Figure 5. Process diagram of our method.



Figure 6. Output of different methods.

5. Evaluation

Because the ACE is sensitive to the source of light, a bright spot appears in the light source in figure 2, but the AWB algorithm avoids the problems well and improves overall brightness, but it may cause a part of the image to become too bright and lead to loss of detail.

Figure 3 shows that the YUV could maintain the basic color of the image in different color spaces, but the overall brightness of the image is not as good as that obtained using HE. However, color deviation was observed in the results of the HE method.

Figure 6(b) shows that although the MSR method enhanced brightness in each channel, its effect was not ideal, and the image contained artifacts and color distortion.

Figure 4(b) shows that the fog effect appeared in the results of the ACE algorithm, further confirming that the effect of the AWB was superior.

In terms of visual perception, compared with other methods in this paper, the details of the image generated by the proposed method were complete, its color was more saturated, and the effect was more realistic.

We used the common mean and mean square error (MSE) to verify image quality. We also added an evaluation index, contrast. It is defined as the degree of contrast between light and dark. The greater the contrast is, the stronger the layering of the image is, and the higher is its sharpness. Table 1. Evaluation parameters of images in figure 6.

Methods	Image III			Image IV		
	Mean	MSE	Contrast	Mean	MSE	Contrast
Input	0.37	-	4.33×10^{-6}	3.39	-	7.82×10^{-6}
MSR	81.95	6.35	0.0020	114.83	6.36	0.0011
AWB	67.24	2.18	0.0048	79.58	3.49	0.0034
AWB_HE	91.88	2.94	0.0122	91.00	4.11	0.0089
AWB_CLAHE	92.32	6.36	0.0054	127.01	6.33	0.0097
Ours	70.91	2.64	0.0052	89.84	4.00	0.0036

Table 1 show that all the proposed methods improved the brightness of the image. The effects of the MSR and AWB_CLAHE were more prominent, possibly because of excessive enhancement.

The values of the mean and MSE for our method show that it enhanced the brightness of the image to a greater extent and provided higher contrast than the AWB method, which, however, had stronger anti-interference ability. This indicates that gamma conversion improves image brightness and contrast but also increases noise. Compared with the AWB method, the image contrast was improved after adding the gamma transform, which indicates that this improved the image effect to some extent.

In summary, our method is more consistent with the characteristics of the human eye, and delivers a better visual effect than prevalent methods for enhancing image brightness.

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6. Conclusion

This paper proposed a contrast enhancement algorithm for dark images based on the AWB and gamma transform that also reduces noise to a certain extent. Moreover, it significantly reduces the amount of computation needed to satisfy the requirements of real-time processing.

Compared with other methods of quantitative analysis, our method makes the transition in image brightness more natural, and the effect is more significant and stable.

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