Night Color Image Enhancement via Statistical Law and Retinex

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Abstract - *Due to the uneven distribution of light at night, the quality of the night color image is usually unsatisfactory. To solve this problem, in this paper, we propose a new statistical method based on the retinex. The algorithm analyzes the transformation relationship between the nighttime image and illumination image by the algorithm of Michael Elad and MSRCR algorithm. Through this transformation, we can accurately and quickly get the illumination image. Then, we can get the resulting image successfully based on the retinex. Our algorithm can greatly enhance the image contrast and brightness, recover image details, eliminate the "halo effect" efficiently, and accelerate the computational speed remarkably. Experiments on different nighttime images demonstrate the effectiveness of our approach.*

Keywords: *statistical law; image enhancement; night color image*

1 Introduction

The night color image enhancement is of great importance in both the computational photography and computer vision. First, it can effectively increase the visibility and surrealism of the scene. Second, artificial illumination light distributes unevenly at night leading to weakening the quality of monitoring photos and increasing the difficulty of surveillance. Thus, the night color image enhancement can promote the video surveillance .Last, the input images of most computer vision algorithms (e.g., the photometric analysis algorithm) are daytime images. Thus, the night color image enhancement can increase the scope of such algorithms by enhancing nighttime images.

However, the night color image enhancement is a challenging task. Currently, the main techniques for the night image enhancement are the image fusion and image enhancement. Image fusion techniques include two categories: one is the fusion of the nighttime image and visible image [1, 2] and another is the fusion of the nighttime image and infrared image [3, 4].These methods require multiple different spectral images collected in the same scene and have high computational complexity .The main techniques for the image enhancement include contrast stretching, slicing, histogram equalization, and some algorithms based on the retinex [5-11], etc. Of all those algorithms, the algorithm based on the retinex has acceptable results, but it will produce the "halo effect" and high time complexity.

In this paper, we propose a novel algorithm for enhancing the night color image based on the statistical law and the retinex. We assume that there is a transformation on the brightness components of the pixel values between the nighttime image and illumination image. Therefore, through this transformation, we can accurately and quickly get the illumination image. Then, we can get the resulting image successfully based on the retinex. The resulting image retains image details and exhibits higher brightness, so that the overall image looks more harmonious and natural. Our algorithm is simpler and faster compared to the other algorithms.

The rest of this paper is organized as follows. In section II, overview of retinex theory is given. In Section III, the proposed algorithm is described in detail, which contains two parts: analysis of the transformation law and enhancing the nighttime image. Finally, the experimental results are presented to demonstrate the efficiency of the proposed algorithm in section IV .The conclusion is in Section V.

2 Overview of retinex theory

The Retinex theory deals with the removal of unfavorable illumination effects from a given image. A commonly assumed model suggests that any given image S is the pixel-wise multiplication of two images, the reflection image R and the illumination image L. This model is given in Eq. (1):

$$S = R \bullet L \tag{1}$$

Therefore, if we can get the illumination image, we can quickly get the reflection image. In the actual calculation, a look-up-table log operation transfers this multiplication into an addition, resulting with s = log(S) = log (L) + log(R) = l + r.

3 Analyzing the transformation law and enhancing the nighttime image

We first transform the original RGB space to HSV space, because processing the color image directly in RGB space will lead to color distortion. The HSV space is closer to human visual perception in color perception .Our transformation law is only used in brightness component of HSV space.

Currently, most algorithms often use the filtering method to estimate the illumination image, and achieve good results. In this paper, we use the processing results of some algorithms (the algorithm of Michael Elad [12] and MSRCR [13.14]) as illumination images. Through these two algorithms, we get three images. One is the nighttime image, and the other two are the corresponding illumination images. Their brightness components of HSV space are denoted as L, M and N. For analyzing the transformation law, we get pixels which value is i (0-255) from L. Then, we have a set of coordinates through known pixels. In the same coordinates, we get two sets of pixel values from M and N. The average (j, k) of these two sets are the corresponding value to i. Fig.1 displays the correspondence between i and j, k. In order to facilitate observation, we add a linear which is y=x.

By observing Fig.1, we find the curve of MSRCR on the figure can be represented by a circular arc. But it is too close to the linear which is y = x resulting in that the enhanced image is too bright and loses details seriously. The curve of Michael Elad is roughly like a circular arc except a small part. It is the reason that the resulting images processed by the algorithm of Michael Elad have a stronger noise. Overall, we can use a circular arc to represent the relationship between the input image and illumination image. Obviously, the fitting circular arc should pass the point (255,255). In order to facilitate the calculation, we use two parameters to represent the circular arc. One parameter is x-coordinate (x_0) of the circular center. Another is the intersection (0, λ) of arc and y positive axle. According to the nature of the circle, the y-coordinate (y_0) of the circular center can be expressed as the following:

$$y_0 = \frac{255^2 - \lambda^2/2 - 255 * x_0}{255 - \lambda} \tag{2}$$

The radius(r) of the circular arc can be expressed as the following:

$$r = \sqrt{(x_0 - 255)^2 + (y_0 - 255)^2} \tag{3}$$

The circular arc can be expressed as the following:

$$y = \sqrt{r^2 - (x - x_0)^2} + y_0 \tag{4}$$

Using Eq. (4), we can get the illumination image directly and quickly. The circular arc is shown in the Fig.2.

According to the Eq. (4), we can know that the circular arc takes two parameters called x_0 and λ. The smaller x_0 is, the more obvious the brightness enhancement is. The greater λ is, the more obvious the brightness enhancement is. It can be seen that the darker the input image is, the smaller x_0 is and the greater λ is, and vice versa. Therefore, we assign the average pixel value of the source image to λ. x_0 is represented by the following formula:

$$x_0 = \max(127, round(6000 * \exp^{-\lambda/30})) \tag{5}$$

Where round () is the rounding function which is used to improve the algorithm speed. The minimum size of x_0 is limited to 127 to prevent image distortion. Therefore, we have got a no-argument function to show the relationship between the original image and the corresponding illumination image.

The algorithm is given below:

1) Transform the original RGB data to the HSV data.

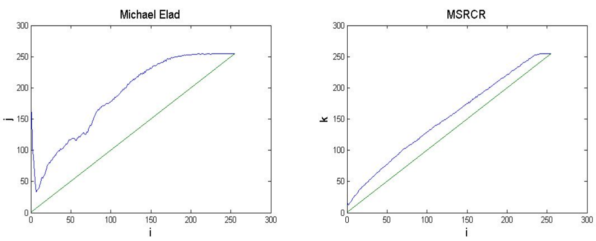
2) Get the illumination image using Eq. (4, 5).

3) Enhance the nighttime image through the retinex theory and the obtained illumination image.

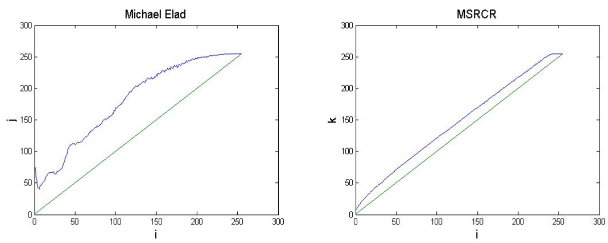
4) Transform the HSV data to the RGB data and show the enhanced image.

4 Comparison and results

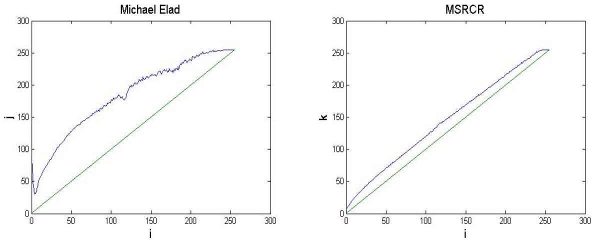
In this section, the proposed algorithm of this paper is compared with the algorithm of Michael Elad and MSRCR algorithm. Fig.3-7 show the experimental results of five scenes.(a) is the original image.(b) shows the enhanced image by the algorithm of Michael Elad.(c) is obtained by MSRCR algorithm.(d) displays the enhanced image by the proposed algorithm in this paper.



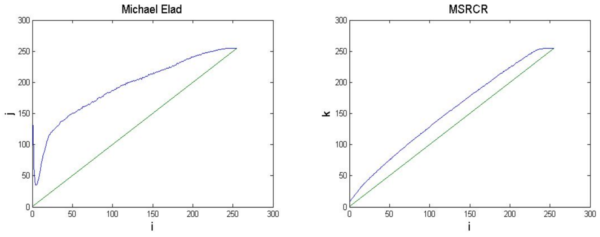
(a)



(b)



(c)



(d)

Fig.1. the corresponding graphs of pixel values of source images and illumination images obtained by the algorithm of Michael Elad and MSRCR algorithm. (a), (b), (c) and (d) are the processing results of four different pictures.

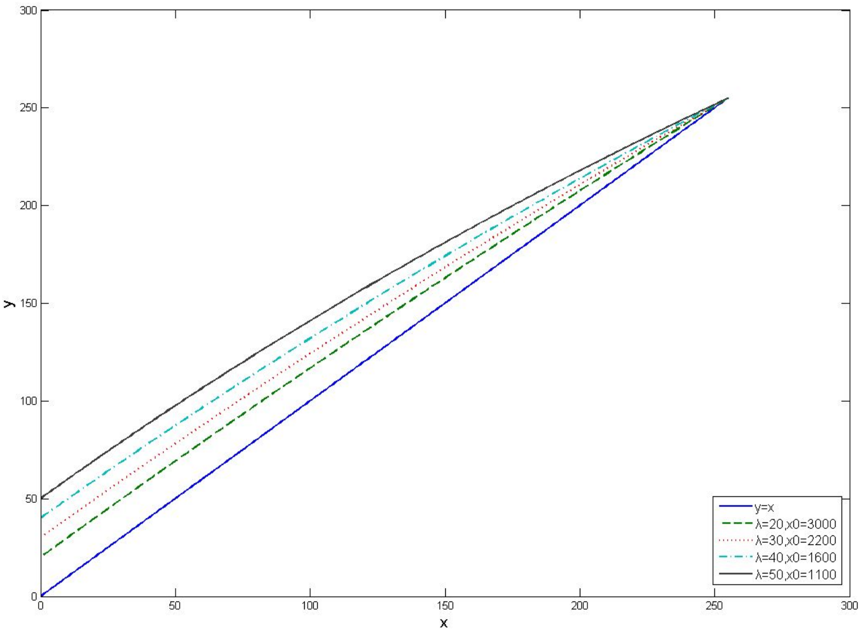


Fig.2. Fitting circular arc

It can be clearly seen from the figures that the three algorithms all have a certain enhancement effect on the nighttime images. The processing results of MSRCR algorithm are too bright leading to atomization phenomenon and loss of details, as shown in Fig.4 (c), Fig.7 (c) and Fig.8 (c). The processing results of Michael Elad's algorithm tend to produce excessive sharpening phenomenon in highlighting edges and the "halo artifacts" phenomenon which is shown in Fig.6 (b) and Fig.7 (b). Moreover, it often leads to noisy amplification in dark areas, as shown in Fig.4 (b), which is mainly due to the unsmooth curve (shown in Fig.1) between source images and illumination images. Compared with the two algorithms, the proposed algorithm can better recover details, eliminates the "halo effect" and suppress noise. Moreover, the results of our algorithm look more harmonious and natural.

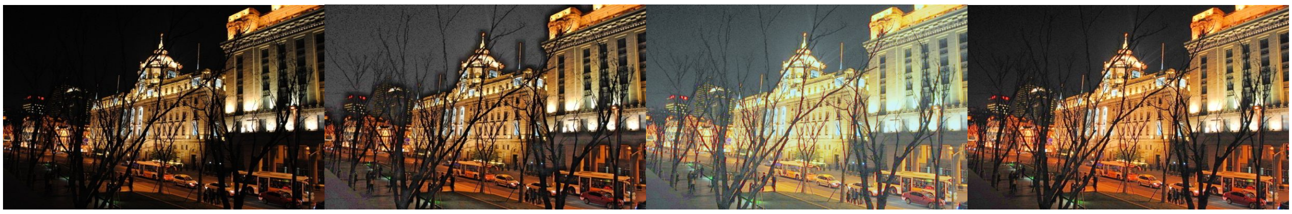
For a more definite description of the experimental results, this paper also uses objective evaluation criteria to test the effectiveness of our algorithm. We examine our algorithm in mean value, standard deviation and time-consuming (Computer configuration: CPU: Pentium(R) 3.00GHz; Memory: 3.00GB; Programming Language: Matlab). The image mean reflects the brightness level of the image; the standard deviation reflects the image contrast; the time-consuming reflects the time complexity of the algorithm. The results are shown in Table 1-5.

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

Fig.3. Scene 1

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

Fig.4. Scene 2



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

Fig.5. Scene 3

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

Fig.6. Scene 4

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

Fig.7. Scene 5

Table 1.Criteria of Assessment of Fig.3

	mean	standard deviation	time-consuming(s)
Source image	32.290669	37.976650	
Michael Elad	74.522833	34.043863	125.203029
MSRCR	122.023486	33.550094	8.073667
proposed algorithm	92.0300	38.6720	1.246996

Table 2.Criteria of Assessment of Fig.4

	mean	standard deviation	time-consuming(s)
Source image	19.074728	28.879643	
Michael Elad	54.979484	32.582415	174.404951
MSRCR	105.600284	41.911008	14.030690
proposed algorithm	87.0683	46.6404	1.724475

Table 3.Criteria of Assessment of Fig.5

	mean	standard deviation	time-consuming(s)
Source image	42.871070	57.089267	
Michael Elad	74.523826	51.653054	177.822975
MSRCR	125.407817	52.732457	11.619577
proposed algorithm	81.8586	61.3861	1.39663

Table 4.Criteria of Assessment of Fig.6

	mean	standard deviation	time-consuming(s)
Source image	43.9788	37.4953	
Michael Elad	85.4186	28.9512	177.513603
MSRCR	145.5552	27.6842	13.096727
proposed algorithm	94.7658	32.4271	1.450654

Table 5.Criteria of Assessment of Fig.7

	mean	standard deviation	time-consuming(s)
Source image	37.186166	32.700994	
Michael Elad	87.693053	47.901984	306.097388
MSRCR	141.732310	45.151938	27.631109
proposed algorithm	101.8945	55.9020	2.418071

As can be seen in Table 1-5, in terms of the mean, MSRCR algorithm has the most significant effect of improving mean, but the enhanced images are too bright overall to protect details. Compared with the algorithm of Michael Elad, the proposed algorithm has a better enhancing effect of the mean which displays the brightness of the whole picture is consistent with human visual perception. In terms of standard deviation, the proposed algorithm is better than the other two algorithms. The proposed algorithm has remarkable enhancement of the image contrast and significant effect of image detail recovery. In terms of time-consuming, the proposed algorithm has lower time complexity than the other two algorithms. Moreover, our algorithm does not need manual control parameters increasing the adaptability of our algorithm.

5 The conclusion

In this paper we present an effective algorithm for enhancing the nighttime image. In our algorithm, we propose a statistical law to present the relation of the original image and illumination image. Using this statistical law and retinex theory, we can accurately and quickly get the resulting image. The algorithm is validated through subjective and objective evaluation, which shows it can eliminate the “halo effect”, enhance the image contrast, recover image details and have low time complexity. In summary, our algorithm is effective to complete the challenging task of enhancing the nighttime image.

6 References

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