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A Night Image Enhancement Algorithm Based on Guided Filtering

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Abstract Colored night images lead to various problems in real life, such as low dynamic range, detail blurring and so on, which are waiting to be solved. For this reason, it proposes an algorithm for night image enhancement based on guided filtering in the paper. This image process includes three main steps. Firstly, by transforming to HVS color space, the targeted image is separated coarsely into two images—base layer image and detail layer image in the result of guided filtering. In the second step, the base layer and detail layer are processed by different strategies selectively and respectively to lighten the whole, but remain details as much as possible. Eventually, the base layer, which has been previously increased contrast, is added detail layer to keep the details and margins. The result image can be retained after reverting to the original color space. Our result illustrates the comparison among result images and images enhanced by other methods, which obviously proves that the algorithm in our paper can obtain relatively better results in the ways of detail enhancement and color fidelity.

Keywords Image enhancement · Guided filter · Night image

1 Introduction

Due to low illumination at night caused by poor light conditions and device itself, the quality of night image gets lower, presented on the overall image grey value and low contrast so hard to identify. In addition, blended background in important parts formed by insufficient light makes local information hard to be recognized. Therefore, enhancing nigh image in civilian life and military usage, such as transportation system, security systems, video surveillance, plays a significant role.

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At present, various methods are created to solve the problems resulted from low illumination image enhancement, including histogram equalization, Retinex [1], MSRcR [2], homomorphic filtering [3], the HDR method and so on.

Based on guided filtering, this paper focuses on the enhancement of night image. The image will be separated into two layers by being coarsely decomposed by guided filter, with the layers are processed by different strategies selectively.

This paper is divided into four parts. The second part will introduce the basic concepts and main characteristics of guided filtering. Then, the third part will elaborate the new method in this paper in the form of graph with detail analysis and how the two layers improve respectively. The fourth part will show the result of our method, which will be compared with MSRcR. The conclusion and prospect can be found in section five.

2 Guided Filter

The guided filter [4], a local linear model, consists of the guidance image I and the filter output q. In a window ω_k where center point is k, it is assumed that the q can be obtained by being transformed linearly by I, so Eq. (2.1) can be obtained:

$$q_i = a_k I_i + b_k, \quad \forall i \in \omega_k \tag{2.1}$$

where the guidance must be set in advance, or directly use the input image I.

It can be deduced that the edge-preserving properties of the method for the local linear relation $\nabla q = a \nabla I$. Therefore, the input image can be smoothed with edge preserved.

Compared with traditional kernel function, the guided filtering achieves higher performance in edge-preserving and detail enhancement with non-approximate linear-time algorithm, which due to the independent computational complexity from the linear-time algorithm. It can use in various computer vision and computer graphics applications including detail enhanced for a night image in the paper.

3 Night Image Enhancement

Inspired by the better performance of original detail remaining of guided filtering, this paper creates a new way to adjust the low-illuminated image to high contrast so that enough to be recognized. In the beginning, the RGB color space of the targeted image will be transformed to HVS color space for higher efficiency and better effect in practice. Then the main process of the method will be stated in four steps as followed.

3.1 Layer Decomposition

The first step is to separate the original image into two layers according to practical need.

Set I as the input image and firstly gain the base layer b, we get the base layer by Eq. (3.1).

$$b = \sum_{i} W_i(I) I_i \tag{3.1}$$

where i and j are the pixel and W_i are the kernel function of guided filtering, it can be computed by Eq. (3.2).

$$W_i(I) = \frac{1}{|\omega|^2} \sum_{i \in \omega_k} \left(1 + \frac{(I_i - \mu_k)^2}{\sigma_k^2 + \varepsilon} \right) \tag{3.2}$$

where ω_k are the k-th windows of kernel function and $|\omega|$ are the number of pixels in the window. μ_k and σ_k are the mean value and variance in window. ε is the smoothing factor.

The detail layer d, extracted from the difference value of original image and the base image, can be presented as follow.

$$d = I - \sum_{i} W_i(I) I_i \tag{3.3}$$

3.2 Detail Layer

The detail layer remains the margins and noise of the image. The aim of this step is to selectively strengthen the margins and reduce the noises. Consequently, it is denoised by guided filter and the result is d. Then details are enhanced by Arctan curve figure. The Arctan transformation is showed by Eq. (3.4).

$$d'' = \sum_{i} G_r * \tan(c * d'_i) \tag{3.4}$$

where Gr is the gray dynamic range of the HVS image and c is the coefficient.

3.3 Base Layer

The theory of base layer processing bases on a simple point-wise operation [5], which gains the output O after mapping input I with the coefficient γ as follow.

$$O = 255 * \left(\sum_{i} \frac{I_i}{255} \right)^{\gamma} \tag{3.5}$$

It is assumed that the input image is a gray image or single-channel image in which grey values ranging from 0 to 255. In our algorithm, γ is calculated according to the nearby pixels through an exponential function as follow.

$$\gamma = 2^{\frac{128 - \bar{I}_{i-inv}}{128}} \tag{3.6}$$

where the new coefficient is the inverted low-pass filtered input image.

Equation (3.6) shows that only the pixels whose values are close to 128 will not be changed too much among all pixels. This method could stretch the contrast of the dark and bright regions. If the image is processed in the RGB color space, it will get grayer output than in the HVS color space. In this case, in HVS, the enhanced image can avoid the washed-out effect. With the help of gamma correction, the low-illuminated condition can be improved and the black corner of the image is lighter enough to recognize. The separation and disposition of the base and detail layers can enhance night image while strengthening the important details.

3.4 Image Confusion

The fusion image is achieved by image confusion of base layer and detail layer in the form of simple addition in the single channel in the HVS color space. After returning to RGB color space, the result image can be obtained.

Figure 1 concludes the whole process of our procedure to enhance the night image. It can be found that the dynamic range enhanced base layer is stretched and

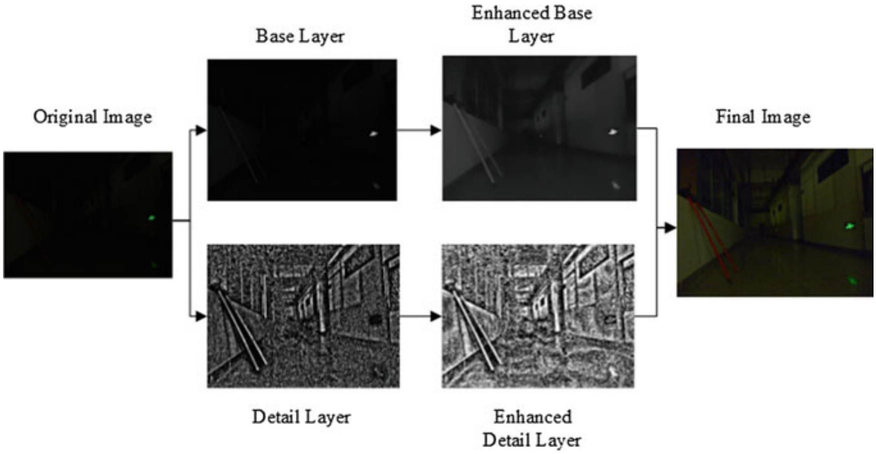

Fig. 1 The process of the image enhancement

the margins in enhanced detail layer get sharp-edged. The final image becomes not only lighter but also clearer.

The parameters that are set for this test will be shown in the next section.

4 Experimental Results and Analysis

The targeted image is firstly separated by guided filtering into base layer and detail layer, in which local window radius is 2 and regularization parameter is 10. Then base layer is processed by gamma of 1/2, while detail layer is processed by Arctan of 8.

Figure 2a is a targeted night image, which shows the corridor building at night that too dark to recognize except a green emergency exit light. Figure 2b is the result image processed by MSRcR, being stretched the dynamic range compared to original image. However, the corner of the room still remains unclearness. Figure 2c shows the result of the algorithm proposed in this paper, which is obviously the lightest and clearest one among three results, especially the edge of the trees, windows and red ladder, gaining best visual effect. The door in the distant place where is not able to identify before also starts to show up after the enhancement.

Otherwise, the quality assessment in Table 1 shows that the algorithm proposed in this paper is better for the higher MSE and Gray mean value than MSRcR, proving that the proposed algorithm can achieve higher range of contrast stretching. In the meantime, the details are kept better as the comparison between the proposed algorithm and reference original image.

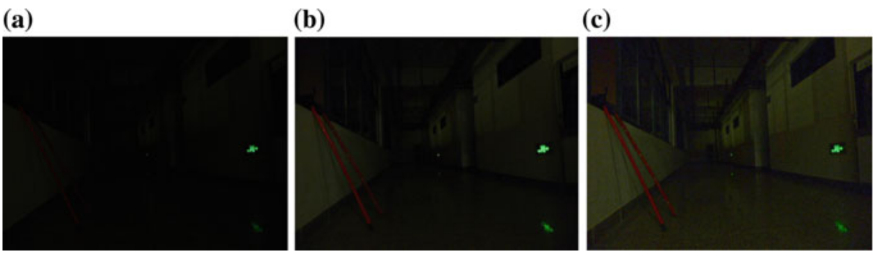

Fig. 2 Comparison of gamma correction, MSRcR and our method. **a** Target picture. **b** Result of MSRcR. **c** Result of proposed algorithm

Table 1 The effectiveness of the experiment

	Targeted image	MSRcR	Proposed algorithm
MSE	–	22.1202	48.8849
Gray mean value	31.3661	13.4980	24.9658

5 Conclusions

This paper proposes a new method for night image enhancement, dramatically improving the edge-preserving compared to other methods. The experiment indicates that the test image is clearer, lighter and closer to the original image. It has higher performance to solve the problems for low contrast image as conclusion. The algorithm may be used in the image recognition and color image artistic rendition.

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