Improved dark channel prior image dehazing algorithm

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Abstract: Aiming at the influence of haze on image such as low contrast, low saturation and color distortion, an improved dark channel prior image defogging method is proposed. Starting from atmospheric scattering model, this method optimizes the dark channel priori rule and obtains the dark channel priori values of two different color spaces. Secondly, the atmospheric light values are estimated for two different color spaces respectively. The average transmittance of RGB color space and Y-channel transmittance of YCbCr color space are calculated. Different weights are given to the two transmittances to restore the image. This method evaluates the experimental results based on structural similarity index, brightness and information entropy. The results show that compared with the algorithm and Fattal algorithm, the defogging image obtained by this algorithm has better visual effect; compared with Zhu algorithm, the calculation is simpler and the color restoration is more accurate.

1. Introduction

Haze is a common natural phenomenon caused by the scattering and absorption of atmospheric light by a large number of tiny water droplets floating in the near-surface surface, or by ice crystal particles. The general vision system is carried out outdoors, sensitive to changes in weather conditions, and smog results in reduced image contrast and recognition, reducing the application value of the image. Therefore, the defogging technology of foggy images has become an area of interest to researchers.

Currently, methods for image defogging fall into two categories: image enhancement methods and image restoration methods. The image enhancement method is based on an image processing technique that enhances image contrast and color resolution. This method does not take into account image loss, and often results in excessive image contrast and loss of important details. Image restoration is designed to observe the physical causes of image degradation. Image restoration provides the advantage of repairing the fog concentration according to the local area of the image, and provides a good defogging effect. In recent years, it has attracted the attention of many scholars. Tan et al. proposed to divide the outdoor image taken in fine weather into blocks and calculate the minimum intensity of each block. The algorithm aims to enhance the contrast, but does not solve the real scene albedo, and the restored image is easily oversaturated; Fattal et al. The rate and surface chromaticity are not related locally. The algorithm depends on the statistical characteristics of the data. However, due to the small amount of color information in dense fog, it is easy to cause statistical unreliability. He et al. propose dark channel prior law and input image first. Increasing the brightness and then estimating the atmospheric light, the defogging effect obtained by the algorithm is better, but the complicated calculation of the transmittance requires a lot of time; Zhu et al. constantly study the HSV color space and propose the difference between the S component and the V component. The image depth information can be approximated, and the color attenuation prior algorithm is proposed. A certain dehazing effect is obtained, but the algorithm has higher time complexity due to excessive constraints.

Summarizing the above methods, this paper proposes a dark channel prior defogging algorithm based on RGB and YCbCr color spaces. Starting from the physical model, the method improves the dark channel prior law, combines the transmittance of two different color spaces, preserves the edge information, assigns a weight to each image and fuses to restore the final fog-free image. The experimental results show that this method achieves better results than the existing image defogging technology. The main improvements in this paper are as follows: 1. Improved dark channel prior by edge protection 2. Estimated atmospheric light value of dark channel using larger window size 3. Transmittance based on RGB and YCbCr for image restoration 4. This method improves the quality of foggy images with better structural detail and a better range of colors.

2. METHOEDS

2.1 Dark channel prior

In computer vision and computer graphics, the fog patterning model described by the following equations is widely used:

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{1}$$

In the formula $I(x)$ is the image to be fogged, $J(x)$ is the foggy image we want to recover, A is global atmospheric light value, $t(x)$ is transmittance. The current known condition is $I(x)$ .Required target value $J(x)$ .The formula (2) is slightly treated and deformed into the following formula.

$$\frac{I^C(x)}{A^c} = t(x)\frac{j^c(x)}{A^c} + 1 - t(x) \tag{2}$$

Among them, the superscript C represents R, G, B three color channels, assuming that the transmittance in each window is constant, define him as, and the value has been given, then find the minimum operation on both sides of equation (3), Available as follows:

$$\min_{y\in\Omega(x)}\left(\min_C \frac{I^C(y)}{A^C}\right) = \tilde{t}(x)\min_{y\in\Omega(x)}\left(\min_C \frac{I^C(y)}{A^C}\right) + 1 - \tilde{t}(x) \tag{3}$$

In real life, even if the naked eye can't distinguish, there will be particles in the air, so when the distance is far away, the effect of fog can still be felt. In addition, the fog can make the naked eye feel the depth of field, so it needs to be preserved when defogging. A certain degree of fog, then by introducing a factor between [0, 1], the formula is corrected:

$$\tilde{t}(x) = 1 - \omega\min_{y\in\Omega(x)}\left(\min_C \frac{I^C(y)}{A^C}\right) \tag{4}$$

2.2 Improved dark channel prior

The minimum value filter is applied to the three colorspaces R, G, and B, and the minimum value is filtered by the window size of 31×31. In this way, the dark channel value of RGB is obtained, and then this method will also be used for the Y channel of theYCbCr color space, thereby obtaining the dark channel value of YCbCr. At the same time, in order to obtain dark channels in two different color spaces, a larger window size is required, as smaller window sizes may produce erroneous estimates of atmospheric light. Dark channel value of RGB color space, as follows:

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{C\in\{R,G,B\}} j^{C}(y)\right) \tag{5}$$

The dark channel value of the YCbCr color space is as follows:

$$J^{dark-Y} = \min_{y\in\Omega(x)}(I^{y}) \tag{6}$$

Among them is the foggy image of the Y channel, and Figure 1 shows the dark channel of the RGB and YCbCr color spaces.

(a) Original image (b) RGB dark channel (c) YCbCr dark channel

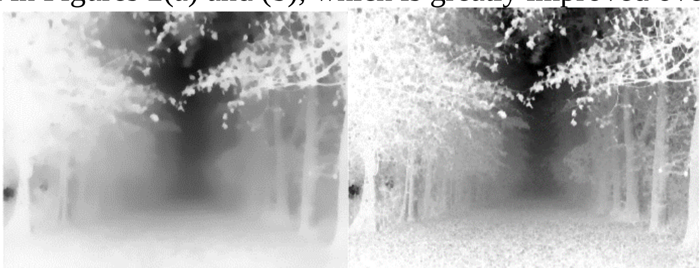
Figure 1. Dark channel prior image in different color space

2.3 Improved transmittance calculation

The transmittance is calculated using the atmospheric light value A from the input image. Three channels are calculated by dividing each channel of the input image by its corresponding value in A. The average transmittance of the RGB color space is calculated as

$$t'(x)=1-\omega\frac{1}{3}\left(\sum_{C=1}^{3}\left(\frac{I^{C}}{A^{C}}\right)\right) \tag{7}$$

To improve the transmittance, firstly, the image is subjected to Laplacian filter filtering, and the output gradient is subtracted from the original transmittance to eliminate unnecessary noise, and then the mean filtering is used for smoothing, and the two methods are adopted. Using the average transmittance of RGB and the Y channel transmittance of YCbCr, respectively, the improved transmittance is shown in Figures 2(a) and (b), which is greatly improved over the previous method.



(a) Rough transmittance (b) Optimized transmittance

Figure 2. Contrast of transmission map effect

2.4 Restoration of fog-free images

At this point, you can restore the fog-free image. Known by formula (1) $J(x)=\frac{(I(x)-A)}{t(x)}+A$ When $t(x)$ is very little, will lead to a large J there by making the image overall white, Therefore, a threshold can generally be set t_0, When t less than t_0, let $t=t_0$ Therefore, the final recovery formula is as follows:

$$J(x) = \frac{I - A}{\max(t(x), t_0)} + A \tag{8}$$

$$J_Y(x) = \frac{I - A}{\max(t_Y(x), t_0)} + A_Y \tag{9}$$

$J(x)$ is an image reconstructed with RGB color space, $J_Y(x)$ It is an image reconstructed with the YCrCb color space. Finally, combining the two images does not reconstruct a fog-free image. Using α combine these images as weights:

$$R(x) = \alpha J(x) + (1-\alpha) J_Y(x) \tag{10}$$

$R(x)$ is the final reconstructed image. After repeated experiment and comparison, the value of the image is best when it is set to 0.55.

3. Results

In order to verify the effectiveness of the proposed algorithm, it is compared with the He, Fattal, and Zhu defogging algorithms. The experimental results of this paper are all obtained on the CPU Intel Core i5-3230M, 8GB PC, the operating system is Windows10, and the simulation software is Matlab2018a.

3.1 Subjective analysis

In this group of experiments, five images were defogged by different algorithms. The defogging effect is shown in Figure 3~6. In Figure 3~6, (a) is the original fog image; (b) is the defogging effect of the algorithm such as He, the method has poor effect on the edge, and the image will be supersaturated with the halo effect; For the dehazing effect of Fattal and other algorithms, the method weakens the halo effect, but the algorithm fails when the assumptions are not met. For example, in the pictures in Fig. 4 and Fig. 7, there are different degrees of color deviation; (d) is Zhu the algorithm defogging effect, because the method is used to filter the restored image, the high frequency information of the image is lost, the boundary is blurred, and the complexity is high. (e) For the improved algorithm dehazing map, we can see that this paper the algorithm has the strongest defogging effect, and the color is more natural, the brightness is brighter, and the layering of the scene is more abundant.

Figure 3. The defogging effect of the city

Figure 4. The defogging effect of Alpine Area

Figure 5. The defogging effect of forest

3.2 Objective analysis

In the objective evaluation, in order to more clearly compare the performance of different algorithms, three parameters are used in this paper, namely luminance, entropy and structural similarity (SSIM) for comparison. Luminance is the contrast of the image, the larger the value, the better; entropy is the information entropy of the image, indicating the value of the information contained in the image, the larger the better; SSIM is to describe the structural similarity of the two images before and after defogging, the more the structure is preserved In good condition, the more useful information is left in the foggy image, so the higher the value, the better. The maximum is 1.Table 1 shows the comparison of the defogged data of the three foggy images using the He algorithm, the Fattal algorithm, the Zhu algorithm and the algorithm.

Table 1. Quantitative evaluation index values of three images after defogging with different algorithms

Image	Algorithm	SSIM	Luminance	Entropy
City 450×350	original image	1.0000	168.1212	5.7754
	He	0.8856	170.6457	7.0235
	Fattal	0.8749	175.3457	6.4134
	Zhu	0.8431	191.6547	7.4835
	Proposed	0.8931	188.6798	7.7921
Mountain 550×750	original image	1.0000	136.7479	6.8101
	He	0.7642	140.1659	7.4414
	Fattal	0.8701	145.3749	7.3656
	Zhu	0.6463	135.6741	7.7032
	Proposed	0.8871	146.3157	7.7951
Forest 600×425	original image	1.0000	177.4175	6.3837
	He	0.8691	167.6484	6.5124
	Fattal	0.8852	180.9434	6.7810
	Zhu	0.8924	181.2464	6.9502
	Proposed	0.9046	182.3497	6.9784

4. Conclusion

This paper proposes a dark channel prior defogging algorithm based on RGB and YCbCr color spaces. First, different dark channel values are obtained through different color spaces, and then the transmittances of different color spaces are used for integration, and the transmittance is improved by using a Laplacian filter, and the weight is adjusted by trial and error to perform the final image. Recovery. The simulation results show that the proposed method has higher accuracy for fog estimation, and the reconstructed image has better color contrast and effectively reduces the halo effect. The obtained image quality is better than that of him, Fattal, Zhu and other algorithms, better practical results.

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