ISSN 2616-5775 Vol. 5, Issue 14: 27-32, DOI: 10.25236/AJCIS.2022.051404

Low Complexity and High Robustness Image Dehaze Algorithm

Changhao Ding[1,a,*]

[1]School of Physics and Information Engineering, Fuzhou University, Fuzhou, Fujian, 350100, China
[a]021900805@fzu.edu.cn
[*]Corresponding author

Abstract: *This paper proposes a low complexity, high robustness dark channel prior image dehaze method. This method addresses the shortcomings of the 'dark channel prior' dehaze method by Kaiming He et al. Firstly, for the scenario of 'dark channel prior' failure, the 'linear stretching' method is proposed to estimate the dark channel after fog removal, then fuse the two 'dark channel' images, and the modified transmissivity is finally obtained. Secondly, because the introduction of the 'Guided Filter' increases the computation of the algorithm, this paper raises the 'pixel-based transmissivity estimation' proposed to remove the 'Guided filter', which not only saves hardware resources, but also eliminates the 'block effect' and 'Halo effect'.*

Keywords: *Image Dehaze Algorithm, Dark Channel Prior, Low Complexity Dehaze Algorithm, High Robustness Dehaze Algorithm*

1. Introduction

Under the interference of atmospheric haze, the atmospheric scattering is serious, which makes the quality of collected digital images seriously reduced, which is not conducive to the extraction of image features. It is important to remove the haze effects from images effectively.

The image dehaze algorithm is mainly divided into two kinds: one is the traditional method which is based on the image enhancement, and the other is the image recovery method based on the physical model[1]. Image enhancement-based dehaze methods do not need to study the physical model of 'image quality reduction', but rather by directly increasing the contrast of the image, or improving the image information or image content that the human eye wants to see. The advantage of image enhancement based methods is that well-established image enhancement algorithms can be applied. However, the disadvantages of this method are also very obvious, which will cause image information loss and distortion. The image dehaze method based on the physical model studies the physical process in which the haze affects the image quality, and establishes the image quality reduction model to compensate for the degradation and quality reduction process. This approach is highly targeted and can better handle image dehazing in complex scenes. The disadvantage is that such methods generally require depth of field (DOF) or atmospheric conditions information. But under realistic conditions, the obtained reduced quality images do not have any additional calibration information of DOF and atmospheric conditions.

The existing image dehazing based on physical model method is mainly divided into three categories: based on atmospheric light polarization characteristic[2], based on image depth[3], and based on prior information[4]. Kaiming He et al.[5] proposed that the 'dark channel prior' -based dehaze method is a relatively typical method of the prior-based methods. The method summarizes 'dark channel priors' based on statistics and then estimates the transmission of the scene to recover the fog image, but 'dark channel priors' fail when the objects in the scene are too bright or similar to atmospheric illumination.

2. Dark channel prior dehaze method

This section cites the dark channel prior dehaze method proposed by He et al. The dark channel prior is based on the observation of a great quantity of fog-free images[6]: at least one of the R, G, and B channels of the image is very low or approaching zero. That is, for any image J, its dark channel can be expressed as a mathematical expression (1):

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}} J^c(y)\right) \quad (1)$$

J^c is the color channel of image J, and Ω(x) is the local image block with center x. Therefore, the above equation can be summarized as finding the minimum value in the three channels of R, G, and B in the local image block. For colorful fog-free images, the value of the dark channel in the non-sky regions approaches to zero, which is the definition of the dark channel priori. That is the formula (2):

$$J^d \rightarrow 0 \quad (2)$$

The mathematical expression for image recovery for the Dark Channel Prior is (3):

$$J(x) = \frac{I(x)-A}{\max(t(x),t_0)} + A \quad (3)$$

I (x) is the scattering intensity reaching Camera; $A = E_\infty(\lambda)$ represents the atmospheric illumination, namely the atmospheric light scattering intensity at infinity; t (x) represents the transmissivity; and t_0 is the minimum threshold to reduce the distortion noise caused by the approaching zero transmissivity in the sky when restoring the image. In practice, He uses the top 0.1% pixels with the largest brightness of the dark channel pixels to estimate atmospheric illumination, reducing the impact of sunlight, etc.

Kaiming He et al. using dark channel priors to estimate the transmissivity of the foggy images. Assuming that the atmospheric illumination is given (the atmospheric illumination estimation method is as described above), the estimated transmissivity is given as the formula for (4):

$$\tilde{t}(x) = 1 - \omega\min_c(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \quad (4)$$

A^c indicating the atmospheric illumination, $I^c(y)$ is the scattering intensity reaching the Camera, ω(0 < ω ≤ 1) is the parameter set the extent of dehazing, and the fog is completely removed at ω =1.

In practice, the transmissivity needs to be corrected to avoid the 'block effect'. He et al.[7] proposed correcting transmissivity using a guided filter. The core assumption of the guided filter is that the relationship between the guide diagram I and the filter output q is locally linear. Assuming that q is a linear transformation of I in a window centered on the pixel k, there is an equation (5):

$$q_i = a_k I_i + b_k, i\epsilon\omega_k \quad (5)$$

(a_k,b_k) is the linear coefficient, ω_k assumed as a constant in the window. See the linear coefficients in equation (6) and (7):

$$a_k = \left(\frac{1}{|\omega|}\sum_{i\epsilon\omega_k} I_i P_i - \mu_k \bar{p}_k\right)(\sigma_k^2 + \epsilon)^{-1} \quad (6)$$

$$b_k = \bar{p}_k - a_k\mu_k \quad (7)$$

μ_k and σ_k^2 are the mean and variance of the image I in the local window ω_k; $|\omega|$ representing the number of pixels in the window; $\bar{p}_k = \frac{1}{|\omega|}\sum_{i\epsilon\omega_k} P_i$ is the mean of the input image p in the local window.

The dehazing effect of the 'dark channel prior' algorithm is shown in Figure 1:

(a) *(b)*

Figure 1: (a) foggy map (b) defogging map

3. Dark channel prior image dehaze method with low complexity and high robustness

3.1. Disadvantages of the dark channel prior model

The 'dark channel prior' dehaze method is low robustness because when the image is a special scene, such as a single color and near gray objects (such as gray buildings, light sources, white clouds, etc.), the

ISSN 2616-5775 Vol. 5, Issue 14: 27-32, DOI: 10.25236/AJCIS.2022.051404

'dark channel prior' is no longer true, that is J_{dark} is no longer tending to zero, and the algorithm fails, see Figure 2. Besides, it requires a 'guided filter' to correct the transmissivity, thus increasing the complexity of the algorithm.

(a) (b) (c)

Figure 2: (a) Input image; (b) output image; (c) transmissivity image[5]

3.2 Modification method of atmospheric transmittance

We propose an optimized dehaze algorithm. The most important point of the dark channel prior, which is $J_{dark} \rightarrow 0$. However, in practice, the image does not guarantee that $J_{dark} \rightarrow 0$ remains true due to different scenes. We use a new way to estimate transmissivity as formula (8):

$$\tilde{t}(x) = \left(1 - \min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)\right)\left(1 - \min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{J^c(y)}{A^c}\right)\right)\right)^{-1} \tag{8}$$

We can obtain the final transmissivity by estimating $\min_{c}(\min_{y\epsilon\Omega(x)}(\frac{J^c(y)}{A^c}))$, the 'dark channel after dehazing'. At the same time, we can enhance the contrast using the traditional dehaze algorithm to estimate the 'dark channel without fog image'. Because only to enhance the contrast, we chose the most common three-segment linear stretching method. Order f (x, y) is the input image, with minimum and maximum gray values are A and B respectively, namely, A = min (f (x, y)) and B = max (f (x, y)). We mapped A and B to 0 and 255, respectively. Define two thresholds $\mathrm{thr_{min}}$ and $\mathrm{thr_{max}}$, and the corresponding mapping values of $\mathrm{map_a}$ versus $\mathrm{map_b}$. Then we get three sections of the slope$k_1 k_2 k_3$, as follows:

$$k_1 = \frac{\mathrm{map_a}}{\mathrm{thr_{min}}} \tag{9}$$

$$k_2 = \frac{\mathrm{map_b} - \mathrm{map_a}}{\mathrm{thr_{max}} - \mathrm{thr_{min}}} \tag{10}$$

$$k_3 = \frac{256 - \mathrm{map_b}}{256 - \mathrm{thr_{max}}} \tag{11}$$

When order f(x, y) is the input image, the output image g (x, y) is shown as follows:

$$g(x,y) = \begin{cases} f(x,y) * k_1 \\ f(x,y) * k_2 \\ f(x,y) * k_3 \end{cases} \quad \mathrm{thr_{min}} \le \begin{cases} f(x,y) < \mathrm{thr_{min}} \\ f(x,y) \le \mathrm{thr_{max}} \\ f(x,y) > \mathrm{thr_{max}} \end{cases} \tag{12}$$

The dark channel of the image without fog can be estimated as equation (13):

$$J_{dark}(x) = \min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{J^c(y)}{A^c}\right)\right) = \min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{g^c(y)}{A^c}\right)\right) \tag{13}$$

In practice, most values of the dark channel of the images without fog are close to zero, and non-zero values are only used to correct the transmissivity. Therefore, add a weight factor $\omega(0 < \omega < 1)$ to the 'dark channel of the images without fog'. The final transmission formula is as follows:

$$\tilde{t}(x) = \left(1 - \min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)\right)\left(1 - \omega\min_{c}\left(\min_{y\epsilon\Omega(x)}\left(\frac{g^c(y)}{A^c}\right)\right)\right)^{-1} \tag{14}$$

3.3 Method of removing the guider filter

'Dark channel prior dehazing' of Kaiming He requires the use of a 'guided filter' to remove the ‘block effect' and the 'Halo effect' introduced by image dehazing. However, the introduction of the 'guided filter'

ISSN 2616-5775 Vol. 5, Issue 14: 27-32, DOI: 10.25236/AJCIS.2022.051404

greatly increases the computational amount of the algorithm, thus increasing the overhead cost of the algorithm hardware. First, the 'guided filter' needs a large amount of local image block, theoretically, the larger the local block of the image, the better the effect. We use 31x31 block can get the ideal effect, but the hardware overhead is too big, and to achieve acceptable effect, at least 9x9 local block (9 line cache and 9x9 window cache). Second, in the 'guided filter', the hardware cost of the mean calculation and the variance calculation and other calculations are also large. Thus, the practicality of the whole algorithm is greatly reduced. To this end, we propose a method that can remove the guided filter.

First, we consider the main reason why the 'dark channel prior' dehaze method introduces the guided filter of He et al.: removing the 'block effect'. The reason for introducing the 'block effect' is that He calculates the transmissivity according to the block as the unit, that is, the image is divided into a fixed size image block, and a transmissivity is estimated in each image block. As shown in Figure 3:

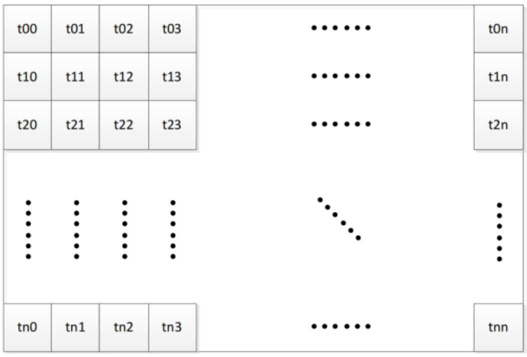

Figure 3: Transmissivity estimation scheme based on image blocks

As can be seen from Figure 3, because there is only one transmissivity in each image block, there may be a transmissivity mutation between the adjacent block and the block, resulting in a 'block effect'. Meanwhile, because the same block is the same transmissivity, the 'Halo effect' will occur when there is a DOF mutation in the image block.

We can find that both the 'block effect' and the 'Halo effect' are because of the image block-based scheme to estimate the transmissivity, and thus the 'guide filter' is used to correct the transmissivity. Therefore, we propose a new scheme: a pixel-based transmissivity estimation scheme. This scheme is shown in Figure 4:

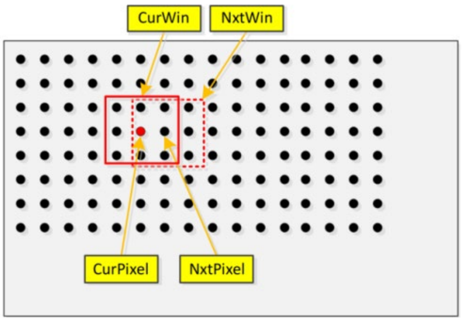

Figure 4: Pixel-based transmissivity estimation scheme (3x3 window)

This scheme calculates the transmissivity in pixels, thereby eliminating the 'block effect' and reducing the 'Halo effect', and, most importantly, no longer requires a 'guided filter'. This saves the hardware resources.

4. Simulation results and analysis

4.1 The overall process of the algorithm

The above section presents an improvement of the dark channel prior dehaze method. The overall process of the improved algorithm (Figure 5) is as follows:

ISSN 2616-5775 Vol. 5, Issue 14: 27-32, DOI: 10.25236/AJCIS.2022.051404

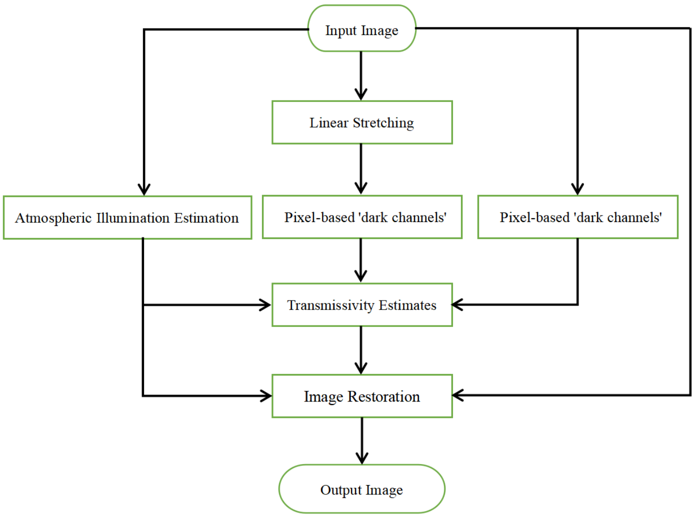

Figure 5: Flow chart of the algorithm

Firstly, estimate atmospheric light, estimate the dark channel of the input image after linear stretching, and estimate the dark channel of the input image directly. Secondly, the modified transmissivity was obtained from the fusion of the two ‘dark channel’ images and the calculated atmospheric illumination. Then, get the recovered image. Finally, output the image.

4.2 The effect of the algorithm

The algorithm is applied to recover the reduced quality of collected foggy digital images. The test effect is compared with the 'dark channel prior' algorithm. The results are shown in Figures 6-7.

(a) (b) (c)

Figure 6: (a) The original image, (b) the 'dark channel prior' dehazing (c) the algorithm proposed

(a) (b) (c)

Figure 7: (a) The original image, (b) the 'dark channel prior' dehazing (c) the algorithm proposed

After the comparison of the dehaze effect of the two algorithms, it can be seen that the 'dark channel prior' algorithm and the algorithm proposed in this paper both have a certain dehaze effect, and the image contrast is improved compared with the original image.

Meanwhile, by comparing the algorithm proposed in this paper with the 'dark channel prior' dehaze algorithm, it can be seen that after processing through the 'dark channel prior' dehaze algorithm, the image color distortion is unusual, and the image edge information distortion is more serious.

ISSN 2616-5775 Vol. 5, Issue 14: 27-32, DOI: 10.25236/AJCIS.2022.051404

5. Conclusion

This paper introduces the traditional image enhancement-based dehaze method and image dehaze method based on the physical model. The most typical representative of image dehaze method based on physical model is 'dark channel based image dehaze method'. The dark channel-based image dehaze method still has the following disadvantages:

First, the 'dark channel prior' dehaze method is poor of robustness, because when the image is some special scene, such as a single color and a large number of close to gray objects exist, the 'dark channel prior' is no longer valid, that is J_{dark} no longer tends to zero, when the algorithm fails;

Second, the 'dark channel prior dehaze method' requires a 'guided filter' to correct the transmissivity, thus increasing the complexity of the algorithm.

To address these problems mentioned above, this paper presents a low complexity and high robustness dark-channel prior dehaze method. This method improves the inadequacy of the 'dark channel prior dehaze method'. Through the original image linear stretching and dark channel operation, the dark channel is used to correct the transmissivity estimation, so as to extend the robustness of the algorithm is greatly enhanced, and the 'pixel-based transmission estimation' is proposed, thus saving the guided filter, which greatly reduces the complexity and hardware cost of the algorithm.

References

[1] Zhao, P., Xiong, N. N. , Wang, B. , & Niu, B. . (2021). Review of single image defogging. International Journal of Sensor Networks, 35(2), 111.

[2] Andrew, A. M.. (2001). Geometric partial differential equations and image analysis. Kybernetes, 31(2).

[3] Oakley, J. P., & Satherley, B. L.. (1998). Improving image quality in poor visibility conditions using a physical model for contrast degradation. IEEE Transactions on Image Processing, 7(2), 167-179.

[4] Tan, R. T.. (2008). Visibility in bad weather from a single image. In: 2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR 2008). Anchorage, Alaska, USA. pp. 1-8

[5] He, K., Sun, J. and Tang, X. (2011). Single Image Haze Removal Using Dark Channel Prior. In:2018 2nd International Conference on Computer Science and Intelligent Communication (CSIC 2018). Washington, DC, USA. pp. 2341-2353.

[6] Pei, T., Ma, Q., Xue, P., Ding, Y., Hao, L., & Yu, T. (2019) Nighttime Haze Removal Using Bilateral Filtering and Adaptive Dark Channel Prior. In: 2019 IEEE 4th International Conference on Image, Vision and Computing (ICIVC). Xiamen, China. pp. 218-222.

[7] He, K., Sun, J. and Tang, X. (2010). Guided image filtering. IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, no. 6, pp. 1397-1409.