A Dark Channel Image Haze Removal Algorithm based on Compensation Mechanism

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Abstract — **Dark channel priori is a simple and effective single image haze removal algorithm, which can be used to estimate the transmittance in the scene with fog. The recovered image is clear and natural. However, in the primary algorithm, the processing effect for sky areas and bright areas is not ideal, resulting in supersaturated and distorted images after haze removal, affecting the visual effect. For these problems, transmittance compensation mechanism is designed, to judge the proximity of each pixel to the atmospheric light intensity. For those pixels close to the light, it reduces the intensity of its haze removal. Experiments show that the improved algorithm enhances the image haze removal process effectively.**

Keywords-haze removal; dark channel; compensation mechanism;

I. INTRODUCTION

Usually, the image of outdoor scene will be degraded due to the cloudy media (such as fog) in the atmosphere, and the image contrast and color fidelity are also decreased. In order to beautify the visual effect of the image and highlight the image features, image haze removal should be conducted. Image haze removal means to reduce or even eliminate the adverse effects of the particulate matters in the air on the image with specific means. Currently, image haze removal algorithm is mainly classified into two types. One is image enhanced method, which can improve image contrast and local details, such as the histogram equalization method in Literature [1-3], and the Retinex image enhanced algorithm in Literature [4].

The other is atmospheric scattering model method, which can recover the original image by building the degradation model for the scene with fog, such as the curvelet domain-based enhancement method in Literature [5]. In Literature [6-9], fog-degraded image restoration is realized by using polarized light to recover the scene depth information. Tan[10] is the first to conduct image haze removal research based on priori information. Fattal et al. [11] induced propagation image and recover scene light, by estimating the irradiancy of the scene. And He Kaiming et al. [12] proposed the single image haze removal algorithm based on dark channels.

In this paper, for the poor haze removal effect for sky and other white areas in the dark channel haze removal algorithm, a compensation mechanism algorithm is introduced to correct the transmittance of image. Without affecting the haze removal effect for other areas, this algorithm has relatively good haze removal effect for sky and other white areas. Experiments show that the improved algorithm greatly enhances the image haze removal effect.

II. DARK CHANNEL PRIORI MODEL

He Kaiming et al. collected a large number of outdoor fogless images, to study the common features of fogless images by observation and experimentation. They proposed the dark channel priori theory [12], that is to say, in most of the outdoor fogless images, within the small local areas, except for sky areas, the pixel value of at least one channel among Channel R, G and B, is very small, or tends to 0. In general, for a image J, the value of each pixel of its dark channel image is determined according to the following formula:

$$J^{\text{dark}}(x) = \min_{C\in(r,g,b)}(\min_{y\in\Omega(x)}(J^c(y))) \tag{1}$$

In which, J^C means any color channel of the primary image J, and x refers to the small local areas, with x as the center. Except for sky area, the value of $J^{dack}(x)$ is small, close to 0. If J is fogless image or a sunny-day image,

$$J^{dack}(x)$$

is called the dark channel image of J.

There exist dark channels in the shadow and the projection of natural landscape, as well as on the surface of dark and bright objects. The reason causing dark channels is as following: red, blue and green are three primary colors. The color channel values of dark objects are generally small, which is easy to understand. However, for the objects with very bright color, such as light green leaves, their dark channel pixel values are generally very small, even close to 0. The pixel value of Channel G is relatively large, while the pixel values of Channel R and B are small. As shadows and colors are commonly seen in the scene which is available to people, dark channels are also common in the color images of these scenes, such as dark buildings, road surface, gray tree trunks, rocks, grasslands, bright flowers, green leaves, blue sea, etc.

III. TRANSMITTANCE ESTIMATION

First, we can assume that the overall atmospheric light intensity A in various areas of the foggy image is the same and known, and then divide the image into small pieces by 9X9. Assuming that the transmittance in each small area is a constant, the transmittance in local areas is expressed with t (x). If minimum filtering is adopted for the imaging model [13,14] of foggy image, we can get:

$$\min_{y\in\Omega(x)}(I^C(y)) = \tilde{t}(x)\min_{y\in\Omega(x)}(J^C(y)) + (1-\tilde{t}(x))A^C \tag{2}$$

C□{r , g ,b} means any image channel. The above process is performed in Channel R, G and B respectively. Thus, the formula above equals to

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

Further, when the above equation is minimized among three color channels, we can get

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

According to dark channel priori principle, the $J^{dack}(x)$ of fogless images should be close to 0. Therefore, we can get

$$J^{\text{dark}} = \min_C(\min_{y\in\Omega(x)}(J^c(y))) = 0 \tag{5}$$

As atmospheric light intensity A is usually a relatively large value,

$$\min_C(\min_{y\in\Omega(x)}(\frac{J^c(y)}{A^C})) \to 0 \tag{6}$$

After substituting (6) into (4), we can obtain transmittance:

$$\tilde{t}(x) = 1 - \min_{\text{C}}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^C})) \tag{7}$$

We can see that $\min_C(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^C}))$ is the result obtained by means of normalization processing of the dark channels of the foggy image with A. Thus, transmittance t(x) can be obtained through finding the dark channel values of the foggy image.

However, in most situations, if the fog in the image is removed almost completely, the image will look unreal, and even unclear. At the same time, the sense of distance between long shot and close shot in the image will disappear. Therefore, we add a constant ω (ω□[0,1]) in the Formula (8) to remain some fog over some distant views and protect the authenticity of the image. At the same time, it can also meet the requirement for image resolution after haze removal. ω value is related to the concentration of fog, illumination intensity, etc. According to experiment results, the heavier the fog is, the more the fog remains after haze removal, and the bigger ω value is, close to 1. Otherwise, the thinner the fog is, the smaller ω value will be. In this paper, ω=0.95, namely, define

$$\tilde{t}(x) = 1 - \omega\min_{\text{C}}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^C})) \tag{8}$$

IV. TRANSMITTANCE COMPENSATION METHOD

A series of experiments has shown that the results obtained by means of dark channel haze removal algorithm will be distorted in some special conditions, resulting in supersaturated colors, and/or some color channel overspread. Through observation, it can be seen that, as shown in Figure , most of the areas with poor haze removal effect are sky area, a large area of white building, and other bright areas. It is difficult to find the point with pixel value close to 0 in these areas. Therefore, dark channel priori will fail in these areas. This limits the applicable range of dark channel priori. In order to use the dark channel priori haze removal algorithm to process the defogged images in different scenes, an improved algorithm is proposed in this section.

In accordance with the atmospheric light intensity estimating algorithm, when the bright areas in the image is very large, the pixels in these areas may be regarded as atmospheric light values. According to the transmittance evaluation formula, it can be seen that when I value is close to atmospheric light intensity A, transmittance t(x) value will be very small, even to 0. It should be mentioned that we estimate the transmittance distribution with the existing algorithm. The accuracy of estimated transmittance is subject to dark channel priori principle. However, based on the previous analysis, the bright area in the image does not comply with dark channel priori principle obviously. Thus, if we still use the above algorithm to calculate the transmittance distribution, the transmittance in these special areas is not consistent with the actual value, and the haze removal effect is also not ideal. If some areas are not comply with dark channel priori principle, the formula can be changed into:

$$\tilde{t} = \frac{1 - \min_{C}(\min_{y\in\Omega(x)} \frac{I^C(y)}{A^C})}{1 - \min_{C}(\min_{y\in\Omega(x)} \frac{J^C(y)}{A^C})} \tag{9}$$

As the bright area $\min_{C}(\min_{y\in\Omega(x)} \frac{J^C(y)}{A^C})$ is not close to 0, the denominator in above formula is smaller than 1. It indicates that the actual transmittance value is greater than the estimated value obtained by means of dark channel priori. What calls for special attention is that if there is large bright areas in the place with small depth of field in the image, the pixels in these areas are likely to be selected as atmospheric light. However, there is no dark channel around these areas, the pixel value after filtering is nearly the same with that of atmospheric light. If dark channel priori formula is still used for calculation, the transmittance will be close to 0, which obviously disagrees with actual situation, leading to incorrect results. In most circumstances, most of the distorted areas after haze removal is sky area, large area of white building and other white areas. These areas have a common feature: there is little difference among the pixel values of 3 color channels. The whole tends to white or gray.

Definition:

$$\delta^C_{C\in\{r,g,b\}}(x) = \left| I^C(x) - A \right| \tag{10}$$

In the formula, $\delta^C(x)$ is defined as the relative value of pixel x.

From above, it can be known that the actual transmittance value of the bright area in image is greater than the estimated value obtained by means of dark channel priori. Therefore, even if the relative pixel values of three color channels differ by several pixels, the color difference value of three channels will be enlarged many times. Thus, the recovered fogless image will deviate greatly from the primary image in color, affecting the image effect. What's worse, if there is a greater color channel value (for example, the image tends to be green.), the difference between this color channel and the other two color channels after haze removal will be further enlarged, resulting in a large area of color distortion of restored image, reducing image quality. For above problems, this paper introduces a parameter to improve the evaluation of the transmittance in bright area. This parameter is defined as

$$R(x) = \sum_{C\in\{r,g,b\}} \delta^C(x) \tag{11}$$

In the formula, R(x) means the proximity of the pixel value x in representation image to the atmospheric light A. The smaller the R(x) value is, the closer pixel value x to atmospheric light A is. If R(x) is close to 0, it indicates pixel x is the light intensity of the image.

As discussed above, if some pixel value of image is very close to atmospheric light value, the evaluated value of transmittance will deviate from the actual value, leading to poor haze removal effects. In order to improve image effect, a threshold value R_0 is set for R(x). When the R(x) value of some pixel is smaller than the set value, it shows that the evaluated transmittance deviates from actual transmittance seriously. If the image is recovered directly, there will be serious image distortion, and we need to correct the estimated pixel. If the R(x) value of pixel x is greater than the set value, it indicates that pixel value x is not very close to atmospheric light A, and the estimated transmittance also complies with the actual transmittance. Thus, the image haze removal effect will not be influenced and the value is not required to be corrected. Add a correction item to the transmittance estimation formula. Then the formula is corrected as:

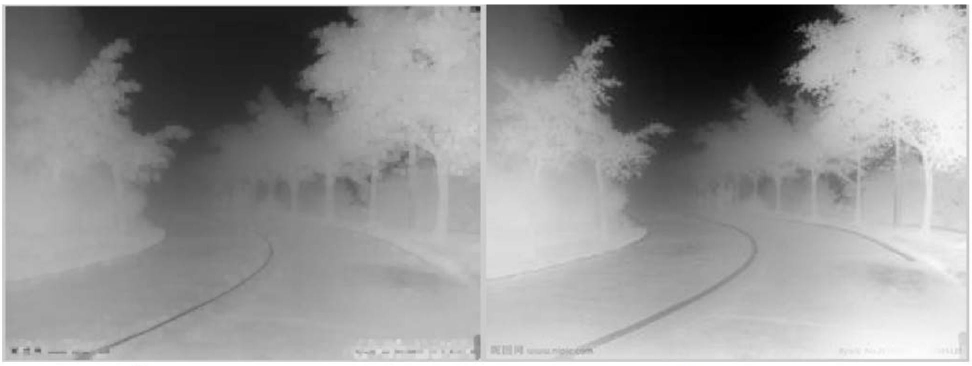
$$\begin{cases} \tilde{t}(x) = 1 - \omega \min_{C}(\min_{y\in\Omega(x)} \frac{I^C}{A^C}) + \alpha \frac{R_0 - R(x)}{R_0}, (R(x) \le R_0) \\ \tilde{t}(x) = 1 - \omega \min_{C}(\min_{y\in\Omega(x)} \frac{I^C}{A^C}), \quad (R(x) > R_0) \end{cases} \tag{12}$$

In the formula , $\alpha \frac{R_0 - R(x)}{R_0}$ is the correction term added. This item is used to offset the deviation between transmittance value and actual value when some pixel value is too close to atmospheric light value. From the formula, it can be seen that only when R(x) value is smaller than the threshold value, transmittance is allowed to be corrected. This guarantees the accuracy of estimated transmittance in any area. The estimation of transmittance adopts segment treatment method. However, due to segment continuity, skipping will not occur to the distribution of image transmittance. Otherwise, the dogging effect will be poor.

V. EXPERIMENTAL RESULT AND ANALYSIS

A. *Parameter setting and analysis*

From the section above, it can be seen that the correction of sky transmittance is related to parameters R_0 and α, as shown in the following figure.



(a) $R_0 = 60$ α = 0.04 (b) $R_0 = 50$ α = 0.02

Figure 1. Influence of transmittance on R_0 and α

Based on a large number of experiments, it can be seen that when different pictures adopt the same parameter values, see Figure 2, the effect obtained is completely different, which is closely related to the ratio of sky area in the picture, and the atmospheric light value A adopted in the picture. In order to establish a mathematical model like this, binarization processing is performed for the test picture.

Based on a large number of experiments, the values of parameter R_0 and α is directly proportional to the area of white parts in binary image. At the same time, it is appropriate that R_0 value range is within [40,60] and α value range is within [0.01,0.05].

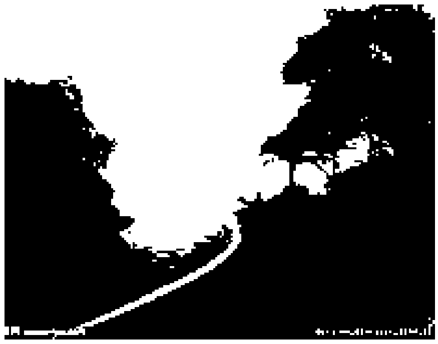
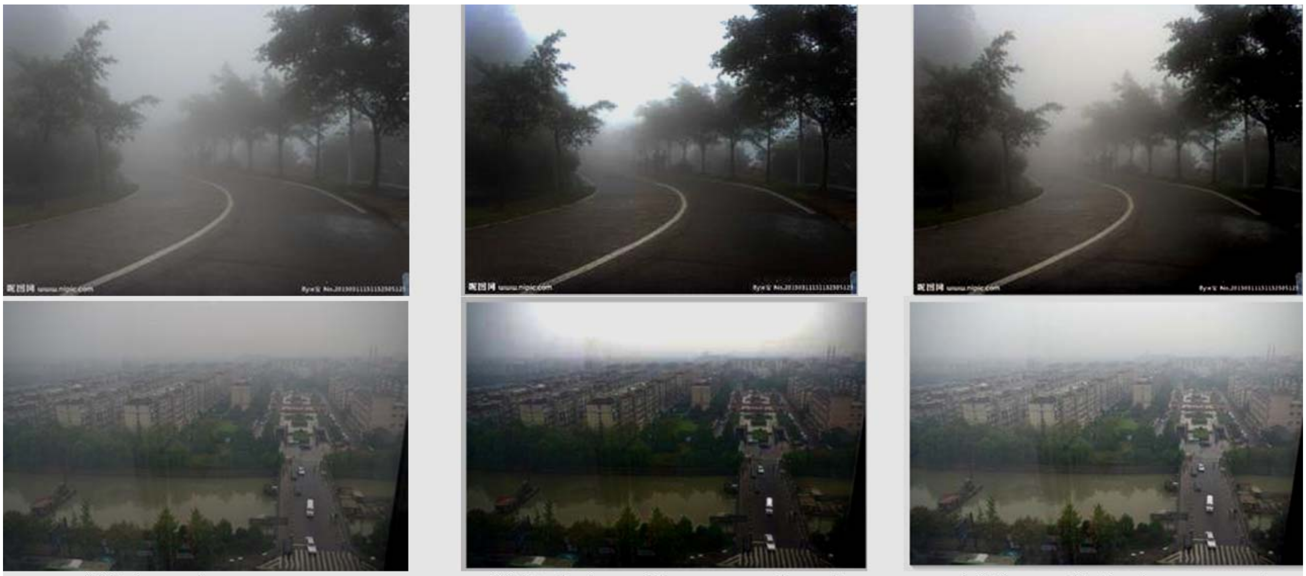


Figure 2. Binarization.



(a) Primary image (b) Dark channel haze removal result (c) The result after improvement

Figure 3. Experiment result

VI. DISCUSSION AND CONCLUSION

The picture shows a comparison of the haze removal results of the existing dark channel and the improved dark channel. After haze removal is performed for sky area by using existing dark channel priori method, “block effect”, or even “distortion” will occur to the restored image. While, the dark channel haze removal is improved with the algorithm described in this paper, the haze removal effect for sky area is much better, and the transition of sky is much more natural.

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REFERENCES

[1] Gonzalez R C, Woods R E. Digital Image Processing. Read-ing, MA: Addison-Wesley, 1992.

[2] Kim T K, Paik J K, Kang B S. Contrast enhancement sys-tem using spatially adaptive histogram equalization with temporal filtering. IEEE Transactions on Consumer Elec-tronics, 1998, 44(1): 82−87

[3] Stark J A. Adaptive image contrast enhancement using gen-eralizations of histogram equalization. IEEE Transactions on Image Processing, 2000, 9(5): 889−896

[4] Joshi K R, Kamathe R S. Quantification of retinex in en-hancement of weather degraded images. In: Proceedings of the 2008 International Conference on Audio, Language, and Image Processing, 2008. Shanghai: IEEE, 2008. 1229−1233

[5] Ramesh Neelamani,Anatoly I. Baumstein,Dominique G. Gillard,Mohamed T. Hadidi,William L. Soro.Coherent and random noise attenuation using the curvelet transform. The Leading EDGE . 2008

[6] Schechner Y Y, Narasimhan S G, Nayar S K. Polarization-based vision through haze[J]. Applied Optics, 2003,42(3): 511-525.

[7] Shwartz S, Namer E, Schechner Y Y. Blind haze separation[C]//Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference on. IEEE, 2006,2:1984-1991

[8] Schechner Y Y, Averbuch Y. Regularized image recovery in scattering media[J]. Pattern Analysis and Machine Intellgence, IEEE Transactions on, 2007,29(9):1655-1660

[9] Zhu Q S,Mai J M,Shao L.A fast single image haze removal algorithm using color attenuation prior. IEEE Transactions on Image Processing . 2015

[10] Tan R T. Visibility in bad weather from a single image[C]//Computer Vision and Pattern Recognition, 2008, CVPR 2008. IEEE Conference on. IEEE, 2008:1-8

[11] Fattal R. Single image dehazing[C]//ACM Transactions on Graphics. ACM, 2008, 27(3):72.

[12] He K, Sun J, Tang X. Single image haze removal using dark channel prior[J]. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 2011,33(12):2341-2353.

[13] Narasimhan S G. Models and algorithms for vision through the atmosphere[D]. Columbia University, 2003.

[14] McCartney E J. Optics of the atmosphere: scattering by molecules and particles[J]. New York, John Wiley and Sons, Inc., 1976. 421 p., 1976, 1.

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