Research on Foggy Image Enhancement Algorithm based on Improved Dark Channel Prior

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Abstract

The complexity of the traditional dark primary de-fog algorithm is high, the transmittance estimation is not accurate enough, and the fog is too single, the image after the fog enhancement needs to be further improved.To solve these problems, an improved dark colors prior to fog enhancement algorithms. First, the rough transmittance is compensated, and then introduce adaptive correction propagation rate to improve the original algorithm to fog over a single case,the rough transmittance is then refined by guided filtering,finally, the contrast of the image is improved by gamma correction.Through experimental demonstration analysis,The proposed algorithm can be improved effectively fog image degradation and improve image clarity.

Keywords

Image Defogging, Dark Channel Prior, Adaptive, Guide Filtering, Gamma Correction.

1. Introduction

Environmental pollution is mainly due to the air in the sulfur dioxide, nitrogen oxides and suspended particles caused by a sharp increase in the content, the first two are gaseous pollutants, and the real reason for the latter is the cause of haze. When the haze in the air, will make the sky into a gray. Under the haze of the weather conditions, due to the scattering of particles and refraction effects suspended in the air, so that the imaging system to capture images of the attenuation of light energy scene, but also the introduction of part of the atmospheric light, resulting in a reduction in the contrast of the image obtained after and details lost, it directly affect the quality of the image. In recent years, haze is getting worse, therefore, the de-fog algorithm for the clarity of outdoor images has a very important theoretical and practical value.

At present, the method of clarifying the image of foggy days is mainly divided into image enhancement method and image restoration method. Based on the image enhancement method, there are representative histogram equalization method[1], homomorphic filtering method[2], Retinex theory method[3,4],and these methods enhance the detail of the image by increasing the contrast of the fog image, and improve the visual effect of the image according to the color correction. However, these methods do not take into account the relationship between the depth of field and the concentration of fog and the intrinsic factors of the image in the process of fog image imaging, resulting in the recovery of the image after the color distortion or supersaturation, making the enhancement effect is not good. Based on the image restoration method, this method is based on the image degradation model, to achieve the purpose of de-fog, this method has been processed after the image effect of real image information is more complete, the difficulty lies mainly in the model of the parameters of the estimate. Tare [5] added a special median filter theory to operate the atmospheric dissipation function, and the atmospheric dissipation function is estimated using the smallest channel within the degraded image. However, this method takes more parameters, in practice it is not so easy. Fatal[6] based on the assumption that the transmittance and scene objectives that the projection part of the local irrelevant, and then infer the scene of the radiation, and use complex optimization algorithms to restore images, but this method cannot handle images in thick foggy weather. The above methods either require more complex mathematical models, or need to add additional parameters. In order to solve these problems, He [7] proposed an effective single-image de-fog method based on the dark prior theory. This method presents a novel algorithm for fog image restoration, through a large number of images without fog comparative analysis, firstly, the use of dark original channel map to estimate the atmospheric light and transmittance, and finally use the soft matting method to refine the transmittance, and then restore the foggy image, the algorithm is relatively simple, but the matched optimal transmittance diagram has obvious block effect and the algorithm has high time complexity. Xu [8] proposed the use of bilateral filtering to optimize the rough transmittance, but the effect is not obvious, for the dark primary color failure of the sky area cannot get a good fog effect. Jiang [9] introduced a tolerance mechanism to re-repair the transmittance of bright areas. But the method can not accurately determine the high-brightness area, the introduction of tolerance mechanism is too small, cannot completely eliminate the sky area distortion, tolerance is too large, it is easy to lead to the effect of bright regional restoration failure, fog effect is not obvious.

This paper proposes to first compensate for the rough estimate of transmittance. And then introduce the adaptive correction propagation rate to solve the dark original transcendental algorithm to fog is too single case, and then use the guided filter to refine the rough transmittance. Finally, the image is enhanced by gamma correction to improve the contrast of the image.

2. Dark Channel Prior

2.1 Atmospheric Scattering Model

The atmospheric scattering model is widely used in image de-fog, and its mathematical expression is shown in equation (1):

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

Where: x indicates the pixel coordinate position in the image; I is the target image, that is, the image to be fogged, J is the image after the fog, A is the current scene global atmospheric estimates, t is the current scene of the transmittance, it decreases with the increase in image depth of field, the mathematical model is expressed as:

$$t(x) = e^{-\beta d(x)} \tag{2}$$

From (1) can be obtained after the image to the fog:

$$J(x) = \frac{I(x) - A}{t(x)} + A \tag{3}$$

2.2 Dark Channel Prior to de-fog

He through a large number of clear weather under no fog image statistics found that in the image after the sky and other bright areas, the vast majority of the foggy images of each local area, at least one color channel in R, G, and B channels has a lower intensity pixel. The mathematical expression is as follows:

$$J^{dark}(x) = \min_{y \in \Omega(x)} \left(\min_{c \in (R,G,B)} J^c(y) \right) \tag{4}$$

Where J^c is the value of a color channel of J, and the area $\Omega(x)$ is centered on the area of x, J^{dark} called dark primary image of J,the value of J^{dark} is very low and is close to zero, the above law is called dark channel prior.

We assume that the atmosphere is known, and the transmittance $t(x)$ does not change in a particular region. In the entire image of the three channels, A is the amount of atmospheric light in a positive channel. Both sides of (1) take the minimum operation in the same time. And then at the same time divided by A^c:

$$\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)=t(x)\min_c\left(\min_{y\in\Omega(x)}\left(\frac{J^c(y)}{A^c}\right)\right)+(1-t(x)) \tag{5}$$

According to dark channel prior, J^{dark} as follows:

$$J^{dark}(x)=\min_c\left(\min_{y\in\Omega(x)}\left(J^c(y)\right)\right)\to 0 \tag{6}$$

Therefore, the initial transmittance obtained is expressed as follows:

$$t(x)=1-\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right) \tag{7}$$

However, if the fog is completely eliminated, the image after the fog will appear to be untrue and the depth of the image will be greatly reduced. So He and so on by introducing a constant factor ω ($\omega=0.95$) in the above formula, leaving a part of the fog covering the vision, there are:

$$t(x)=1-\omega\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right) \tag{8}$$

The rough transmittance is estimated from the above equation, He uses a soft-cut method to optimize the transmittance to obtain a refined transmittance. Finally, the reconstructed de-fog image is obtained by the following equation $J(x)$:

$$J(x)=\frac{I(x)-A}{\max(t(x),t_0)}+A \tag{9}$$

Where, the value of t_0 is 0.1 in the method of He. For the value of atmospheric light, In the He method, we first select the largest pixel of the brightness of one thousandth of the dark primary color, and then select the maximum value of these pixels in the original image as the final value of A.

For most of the outdoor images, the above algorithm can achieve a better fog effect, because the dark primary image of most of the pixels can meet the dark channel prior theory. Although this method can achieve good results in most cases, but because it is the use of soft matting to achieve transmittance optimization, resulting in slower. And when the transmittance is grossly estimated, the estimated value is less than the actual value, resulting in an insufficient estimation of the transmittance. And the use of constant propagation rate, making the fog is too single. As a result, some improvements have been made while learning this algorithm.

3. Improved algorithm

3.1 Transmittance compensation

According to Eq. (5), the actual transmittance t_{real} can be expressed as follows:

$$t_{real}(x)=\frac{1-\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)}{1-\min_c\left(\min_{y\in\Omega(x)}\left(\frac{J^c(y)}{A^c}\right)\right)} \tag{10}$$

Because A is a positive number, and the value of J_{dark} is very small, close to 0,so $t_{real}(x)>t(x)$ .Therefore, this paper presents a method of compensating the transmittance, the expression is as follows:

$$t_{actual}(x)=\frac{t(x)}{0.9+\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)} \tag{11}$$

3.2 Adaptive correction propagation rate

Through the study found that, as a result of the constant ω to image defogging, it will have to go the whole fog over a single, for the image near the location of the phenomenon of excessive fog, resulting in close-range image is too saturated, unnatural. For the vision of the image to the degree of fog is not enough, resulting in the fog effect is not obvious. Therefore, this paper uses the introduction of adaptive parameters ω to de-fog the image, the expression is as follows:

$$\omega=1-\partial^{\frac{255-\min_c\left(\min_{y\in\Omega(x)}\left(\frac{I^c(y)}{A^c}\right)\right)}{\beta}} \tag{12}$$

Where, in this paper, $\partial=0.5$, $\beta=50$;

3.3 Guided filtering to optimize transmittance

The rough transmittance is optimized by the soft matting method in He's algorithm, but this approach is too slow, the time complexity is too high, is not conducive to practical application. Therefore, this paper uses the improved guided filter to optimize the rough transmittance map, the complexity of the method has nothing to do with the size of the filter window, not only enough to enhance the edge of the information, but also to achieve a good fog effect.

The pilot filter assumes that there is a local linear relationship between the pilot image I and the filtered output q , which is:

$$q_i=\frac{1}{|\omega|}\sum_{k:i\in\omega_k}(a_kI_i+b_k)=\bar{a}_iI_i+\bar{b}_i \tag{13}$$

Where q is a linear change in the local window with k as the central pixel in the image, (a_k,b_k) is constant in neighborhood ω_k .

By solving the specific cost function and simplifying the result, we can get the final expression:

$$q_i=\frac{1}{|\omega|}\sum_{k:i\in\omega_k}(a_kI_i+b_k)=\bar{a}_iI_i+\bar{b}_i \tag{14}$$

Where, $a_k=\frac{\frac{1}{|\omega|}\sum_{i\in\omega_k}(I_ip_i-\mu_k\bar{p}_k)}{\sigma_k^2+\varepsilon}$, $b_k=\bar{p}_k-a_k\mu_k$, $\bar{a}_i=\frac{1}{|\omega|}\sum_{k\in\omega_k}a_k$, $\bar{b}_i=\frac{1}{|\omega|}\sum_{k\in\omega_k}b_k$. μ_k And σ_k^2 represent the mean and variance of the image I in the rectangular window ω , $|\omega|$ is the number of pixels in window ω .

3.4 Gamma correction

Experiments show that the image after the fog will be dim, the contrast is low, and making the image visual effect is poor. Therefore, this paper proposes to use gamma correction to enhance the contrast of the image, making the image of the dynamic compression range increases, and the details of the image information is more obvious. The mathematical expression of gamma correction is as follows:

$$r'(x,y)=[r(x,y)]^{\gamma} \tag{15}$$

Where, r' represents the corrected output image, r represents the output image, and γ is 0.8.

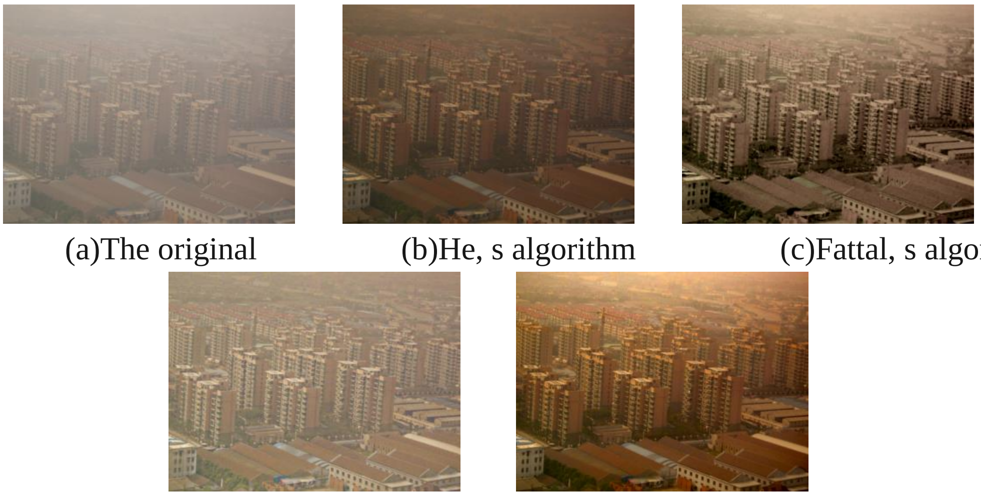
4. Experimental simulation and analysis

This experiment is carried out on the MATALB platform, the MATLAB version is R2013b, the PC processor is Intel (R) Core (TM) i5-2500 CPU @ 3.30GHz 3.60GHz, the memory is 4.00G, the operating system is 64-bit Windows7 Ultimate. All images in this article are from Baidu, Google and other sites.

4.1 Analysis of Subjective Visual Effects

In order to further verify the de-fog effect of the algorithm, in this experiment, we compare the algorithm with He algorithm, Fattal algorithm and Tarel algorithm in a comprehensive way. The limited local block window takes $7*7$ sizes, ω is 0.95.

In this paper, we compare the results of different de-fog enhancement algorithms, and Figure 1 ~ Figure 3 shows the image fogging results of various algorithms, from Fig. 1 (b), Fig. 2 (b) and Fig. 3 (b), it can be seen that the algorithm of He's de-fog enhancement has obvious "block effect" at the edge, so that the de-fog at the edge is not ideal. From Fig. 1 (c), Fig. 2 (c) and Fig. 3 (c), it can be seen that Fattal's algorithm has obvious local degradation of the image after fog enhancement, and the image will produce significant distortion. From Fig. 1 (d), Fig. 2 (d) and Fig. 3 (d), it can be seen that Tarel's algorithm de-fog enhancement image edge is not clear enough, and there is "halo" phenomenon. From Fig. 1 (e), Fig. 2 (e) and Fig. 3 (e), it can be seen that the algorithm of the fog-enhanced image of this paper is bright and retains a small amount of mist to make the image look more real and natural,while enhancing the details of the image information, the effect is better.



(a)The original (b)He, s algorithm (c)Fattal, s algorithm

(d)Tarel, s algorithm (e) this paper algorithm

Figure 1 defogging enhancement Comparative Experiment 1

(a)The original (b)He,s algorithm (c)Fattal,s algorithm

(d)Tarel,s algorithm (e)this paper algorithm

Figure 2 defogging enhancement Comparative Experiment 2

(a)The original (b)He,s algorithm (c)Fattal,s algorithm

(d)Tarel,s algorithm (e)this paper algorithm

Figure 3 defogging enhancement Comparative Experiment 3

4.2 Objective parameter evaluation

In this paper, the effects of four de-fog algorithms are evaluated by the average gradient, information entropy and standard deviation. Where, the average gradient represents the hierarchy of theimage. The information entropy represents the amount of information in the image, the greater the value, the richer the information of the image. The standard deviation indicates the degree of discretization of the image pixels, and the larger the value, the richer the details of the image.

Table 1 ~ Table 3 gives the image objective evaluation index value, can draw the following conclusions: the improved algorithm's index value algorithms are better than others, although the standard deviation of the Fattal algorithm is higher than that proposed in this paper, it is prone to color distortion, making the visual effect of the image after the fog enhancement.

Table 1. Objective evaluation of each de-fog algorithm in Figure 1

	Average gradient	Entropy	Standard deviation
The original	2.2960	6.4581	22.2149
He's algorithm	3.6199	6.6547	25.7647
Fattal's algorithm	6.6504	7.4777	47.7513
Tarel's algorithm	6.3933	6.6846	25.7256
this paper algorithm	6.5304	7.5422	51.9758

Table 2. Comparison of objective evaluation results in experiment 2

	Average gradient	Entropy	Standard deviation
The original	7.3351	7.3339	41.8935
He's algorithm	12.1121	7.4094	64.0755
Fattal's algorithm	16.7513	3.5273	115.4980
Tarel's algorithm	12.9827	7.4074	44.6631
this paper algorithm	11.5610	7.7946	61.0368

Table 3. Comparison of objective evaluation results in experiment 3

	Average gradient	Entropy	Standard deviation
The original	3.5383	6.9840	32.9651
He's algorithm	4.8543	7.1101	37.3172
Fattal's algorithm	7.1799	6.4862	74.2091
Tarel's algorithm	8.2748	7.1074	33.0678
this paper algorithm	5.4124	7.3753	44.3893

5. Conclusion

This paper focuses on the improvement of the fog enhancement algorithm for the prior theory of dark primary colors, and compensates the problem of inaccurate estimation of transmittance. The introduction of adaptive correction propagation rate, to solve the fog is too single problem. The use of guided filtering instead of the original algorithm in the soft matting method, reducing the complexity of the image algorithm. And the use of gamma correction improves the problem of low image contrast after de-fog enhancement. Through the simulation and demonstration, the algorithm can get a better dehumidification enhancement effect, so that the image after the fog enhancement is more clear and natural.

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