Image defogging algorithm based on dark channel prior of adaptive weight

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Abstract. At present, the selection of parameters based on the dark channel defogging algorithm is relatively simple, and it is difficult to adapt to the fog images in different environments. To solve this problem, this paper proposes an adaptive weight parameter defogging algorithm. In this paper, it is found that the weight parameter $\omega$ of demisting has a certain relationship with the atmospheric light value, and based on this relationship, the optimization of demisting effect is realized. In this paper, after the improvement of the original algorithm, the improved method is compared with other methods. The experiment shows that the visual effect of the image after defogging is more real and natural.

Keywords. Dark channel, adaptive weight, atmospheric light value, image defogging.

1. Introduction

Under the condition of haze, the suspended particles in the atmosphere will produce scattering effect on the light, resulting in the phenomenon of image contrast reduction, color distortion and detail blur. Clear images can be used in various fields, but in real life, due to the influence of bad weather, the image quality is often poor, which greatly reduces the application value of the image, among which haze is one of the common bad weather, so the research of image defogging is very important. At present, the main image defogging methods can be divided into two categories: non-physical model based methods and physical model based methods. Based on the nonphysical method, the parameters of the model are estimated by the known constraints, and the clear and natural scene image is finally recovered. This kind of method can better maintain the edge details of the image. In the research of Fattal [1], it is found that the reflectance of the object surface is not locally related to the light transmittance. Based on this, the transmissivity is estimated, and the restored image is obtained according to the atmospheric scattering model. The algorithm solves the distortion phenomenon well, but the restoration effect is poor when the color information is less. Wang et al. [2] found that there is a linear relationship between the fog image and the minimum channel of the fog free image, and proposed an improved method based on quad-tree to estimate the atmospheric light value. Although the method has achieved good restoration results, the color of the restored image is darker. He Kaiming et al. [3] obtained a priori rule after mathematical statistics on a large number of outdoor clear images: in the R, G, B three color channels of most color non fog images, at least one color channel has a very low gray level. Based on this, an image defogging algorithm based on the prior of
dark channel is proposed, which can directly estimate the atmospheric light value and transmittance from a single image.

In the application of fog removal algorithm based on dark channel theory, it is a conventional idea to optimize the transmittance and improve the effect of fog removal. In this method, the weight parameter W of defogging is adjusted adaptively, and the transmittance does not need to be optimized. From the perspective of improving the atmospheric light value estimation results and modifying the image edge position and dark channel value, the research is carried out in order to improve the image color deviation phenomenon and suppress the occurrence of image halo effect.

2. Principle

2.1. Dark channel priori.
The author statistics a large number of non fog images and finds a rule: among the three RGB color channels of each image, the gray value of one channel is very low, almost tends to 0. Based on this priori knowledge, which can almost be regarded as a theorem, the author proposes a dark channel priori defogging algorithm.

The mathematical expression of its dark channel is:

\[ J_{\text{dark}}(x) = \min_{y \in \Omega(x)} \left[ \min_{\gamma \in \Omega(y)} J^c(\gamma) \right] \]  
(1)

where \( J \) represents each channel of the image, \( \Omega(x) \) represents a window centered on pixel \( x \).

First take the minimum value of gray value in three channels of each pixel in the image to get a gray image. Then in this gray image, take a certain size rectangular window with each pixel as the center, and take the minimum value of gray value in the rectangular window instead of the gray value of the center pixel to get the dark channel image of the input image. Filter window size: \( s=2*r+1 \), a priori theory of dark channel: \( J_{\text{dark}} \to 0 \).

2.2. Principle of dark channel demisting.
In the field of image processing, the following models are commonly used as atmospheric scattering models:

\[ I(x) = J(x)t(x) + A(1-t(x)) \]  
(2)

where \( x \) represents the spatial position of a pixel, \( I(x) \) represents the image with fog, \( J(x) \) represents the image with fog, \( A \) represents the atmospheric light value, and \( t(x) \) represents the transmittance.

The prior knowledge of dark primary color refers to: in most areas of the fog free image, there is always a small value of some pixels on a certain color channel, which is 0 or close to 0. The formula can be defined as shown in formula 1, where \( c \) represents a channel of \( r, g \) and \( b \), \( \Omega(x) \) represents a filtering region with pixel \( x \) as the center point, \( J^c(\gamma) \) represents a pixel channel value in \( \Omega(x) \) region, and \( J_{\text{dark}} \) represents a dark primary color value. According to the introduction above, in outdoor fog free images, the dark primary color value is a very small value, which is always close to 0 or 0.

First, assuming that the atmospheric light a value is a constant value, the equation (2) is deformed as follows:

\[ \frac{I'(x)}{A} = t(x)\frac{J'(x)}{A} + 1 - t(x) \]  
(3)

Secondly, assuming that the transmissivity \( t(x) \) of each window is a fixed constant, it is expressed as \( I'(x) \), and both sides of formula 3 are simultaneously calculated by taking the minimum value of the region, we can get:
According to the prior knowledge of dark primary color described above, it can be seen that $J_{\text{dark}}$ is close to 0, and the rough transmissivity $\tilde{t}(x)$ can be estimated:

$$\tilde{t}(x) = 1 - \omega \min_{y \in \Omega(x)} \left( \min_{c} \frac{f(y)}{A^c} \right)$$  \hspace{1cm} (5)

where, $\omega \in [0,1]$ is to retain a small amount of fog to improve the image authenticity. In order to observe the defogging algorithm more intuitively, in this section, equation 1 is transformed as follows:

$$J(x) = \frac{f(x) - A}{\max\{t(x), t_0\}} + A$$  \hspace{1cm} (6)

In the formula, the threshold value $t_0$ is to prevent the case that the permeability $t(x)$ is too small. Generally, $t_0 = 0.1$

2.3. An improved defogging algorithm based on adaptive parameter optimization.

In this paper, an improved adaptive weight $\omega$ method is proposed. According to equation 5, we can see that $\omega \in [0,1]$, the greater the weight is, the higher the degree of defogging is. Considering the authenticity of the human eye image, $s=0.95$ is taken to retain a small amount of fog. However, in a large number of experiments in this paper, it is found that $\omega = 0.95$ is not suitable for all images. The experiments are as follows.

From figure 1, we can see that the defogging effect is not good enough when $\omega = 0.65$, the color saturation is too high when $\omega = 1$, and the sky is divided into obvious dark blue and light blue areas, and the image continuity is very poor, which is not realistic. Therefore, in this figure, $\omega = 0.80$ is better. Where, the atmospheric light $a$ value estimated in Figure 1 is 0.75, which is the same size as the optimal $\omega$ value.

The above experiments can prove that $\omega = 0.80$ is not suitable for all images, because the defogging effect has a great relationship with $\omega$ value, and different images have corresponding $\omega$ value. Therefore, it is not appropriate to set the $\omega$ value as a fixed value artificially. Through the experiment, we find that the closer the $\omega$ value is to the normalized $a$ value, the better the corresponding effect is. Therefore, this paper improves this and takes the $\omega$ value as the normalized a value directly. Formula (5) is optimized and improved as follows.

$$\tilde{t}(x) = 1 - \min_{y \in \Omega(x)} \left( \min_{c} f(y) \right)$$  \hspace{1cm} (7)
Figure 1. The effect of different $\omega$ on defogging effect.

3. Experiment
Refer to Retinex algorithm [2], Fattal algorithm [1], He algorithm [3], literature [5], literature [4] and the algorithm in this paper for comparative experiments, and use the method of subjective evaluation and objective evaluation to compare and analyze the experimental results. The defogging effect of this paper is shown in Figure 2.

The objective evaluation indexes in this paper are peak signal-to-noise ratio (PSNR) [14], structural similarity (SSIM), and information entropy $H$, in which PSNR and SSIM represent the degree of distortion, and information entropy $H$ represent the detail information of the image. The larger the values, the better the image quality. The experimental results are as follows:

|                | Original graph | Retinex | Fattal | He    | Our   |
|----------------|----------------|---------|--------|-------|-------|
| PSNR           | --             | 11.465  | 11.284 | 12.177| 15.804|
| information entropy $H$ | 7.094       | 5.643   | 3.551  | 7.368 | 7.481 |
| SSIM           | --             | 0.779   | 0.557  | 0.785 | 0.890 |
Figure 2. Image defog effect.

Table 1 shows the objective evaluation results of the factory image after defogging by PSNR, information entropy H and SSIM. From table 1, it can be seen that the data after demisting by Fattal algorithm is the worst, which can also be seen clearly from the comparison figure in Figure 2. The three objective evaluation values of the algorithm in this paper are the highest, indicating that in this figure, the algorithm in this paper has achieved the best demisting effect.

4. Summary
In the process of optimizing the defog image, the adaptive weight $\omega$ algorithm is introduced to make the visual effect of the defog image more realistic. The experimental results show that the algorithm in this paper is more realistic and natural than other algorithms in visual effect, and the objective evaluation index is also better. Good results have been achieved, but there is still room for improvement. In the future research, how to improve the speed of the algorithm is taken as the direction of improvement in order to apply to real-time video processing.
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