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Image defogging system and algorithm research based on MATLAB platform

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Yongchang Chen[1], Xiangrui Sun[2], Xiaofeng Qiu[3] and Xinyan Wang[1*]

[1] Department of telecommunications, Tibet University, Lhasa, Tibet, 850000, China

[2] Department of civil engineering and water conservancy, Tibet University, Lhasa, Tibet, 850000, China

[3] Department of telecommunications, Tibet University, Lhasa, Tibet, 850000, China

[1*]Corresponding author's e-mail: king1113@utibet.edu.cn

Abstract: Since the Reform and Opening up, the characteristics of China's high-quality economic development have become more distinctive, the adjustment of economic and social structure has been continuously optimized, the kinetic energy has been continuously enhanced, and the degree of industrialization has been significantly improved. However, it has also caused some environmental problems, and haze pollution is one of them. The haze weather with low visibility has a certain impact on people's daily travel, transportation and navigation. Because the images taken under the haze condition will be degraded to varying degrees and the image details will be lost, the effect of identifying and processing the degraded images in the later stage will be reduced. Therefore, in order to clear and restore the degraded image, we developed a defogging system based on MATLAB software. The system mainly uses histogram equalization, MSR and dark channel a priori defogging algorithms to restore fog degraded images. The results indicate that various defogging algorithms are able to enhance the clarity of the picture to varying degrees. The successful implementation of the defogging system lays a theoretical foundation for the in-depth research and application of fog image defogging processing technology, and has good technical operability.

1. Introduction

In today's world, the development of science and technology is changing with each passing day, and society is developing at a high speed. However, many problems have emerged. Factory chimneys emit a large amount of polluting exhaust gas and cars emit a large amount of exhaust gas, resulting in haze weather. It will make it difficult for image acquisition equipment to work as accurately as when there is no fog [1-2]. In some computer outdoor vision application fields, such as intelligent rail transit, remote sensing image detection and safety automatic monitoring, its image effectiveness is related to the clarity and visibility of outdoor images obtained by image acquisition, and the requirements for outdoor image acquisition quality are relatively high. Up to now, image defogging algorithms are mainly divided into two categories: image enhancement based on image features and image restoration based on physical model [3]. The former mainly completes the defogging by improving the image quality and improving the overall image visual effect. Its classical algorithms mainly include histogram equalization, MSR, wavelet image transform, etc. MSR algorithm is gradually improved from a single multi-scale algorithm (SSR) for more than 50 years. It can not only maintain the high fidelity of color image and information compression, but also enhance color information under certain conditions, [4]. The defogging algorithm based on physical analysis model is mainly based on the principle model of atmospheric light scattering in foggy days. The image restoration results of this kind of defogging method are natural and have little distortion, but the image parameters change more and the implementation is more complex [5]. In recent years, great progress has been made in the technical research of image restoration and removal methods based on fog a priori scientific knowledge or theoretical assumptions. He proposed a dark channel a priori through years of observation and analysis, and completed the restoration of fog images according to the atmospheric scattering illumination model [6]. This paper designs an image defogging system based on MATLAB, and compares several classical defogging algorithms, which lays a foundation for the research and application of restoring degraded images in foggy days.

2. common image defogging algorithms

2.1 principle of histogram equalization algorithm

Image histogram represents the probability of each gray level in the image. If an image has N pixels, r_k represents the gray level corresponding to the k-th gray level, L represents the number of gray levels, and n_k represents the number of pixels of gray level r_k, then the histogram can be defined as:

$$P(r_k) = \frac{n_k}{N}, k = 0,1,2,...,L-1. \qquad (1)$$

Histogram equalization is to change the histogram distribution of the image into an approximately uniform distribution, so as to enhance the contrast of the image. It is divided into two categories: global histogram equalization and local histogram equalization. The former is to equalize the histogram of the whole image, while the latter is processed by dividing multiple sub blocks. The processing steps of histogram equalization are as follows:

1) Scan each pixel of the original gray image in turn to calculate the gray histogram of the image;
2) Calculate the cumulative distribution function of gray histogram;
3) According to the principle of cumulative distribution function and histogram equalization, the mapping relationship between input and output is obtained;
4) Finally, the image is transformed according to the mapping relationship.

2.2 principle of Multi-scale Retinex (MSR) algorithm

Retinex theory, the most widely used a priori constraint in the solution of eigen image decomposition problem, is that it is a composite word composed of English words retina and cortex. The theory focuses on explaining the perception model of color and brightness of human visual system. The imaging process can be expressed as:

$$I(x,y) = R(x,y) * L(x,y) \qquad (2)$$

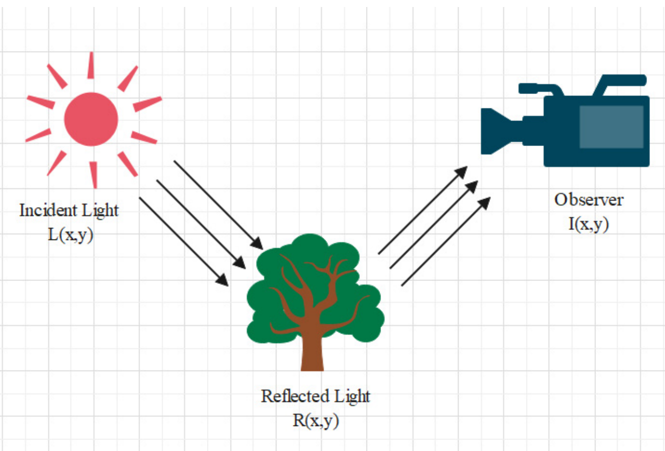

Figure1. schematic diagram of retinex model

Where I(x, y) represents the original image, R(x,y) represents the reflected image, and l(x, y) represents the incident illumination image. Perform logarithmic operation on equation (2), then:

$$\lg[R(x,y)] = \lg[I(x,y)] - \lg[L(x,y)] \tag{3}$$

Single scale Retinex constructs a Gaussian surround function, then filters the RGB three channels of the image respectively, and then subtracts the original image and the illumination component in the logarithmic domain to obtain the reflection component, which is used as the output image. The algorithm can enhance the details of the image. Expressed as follows:

$$r_{SSRi}(x,y) = \lg[R_i(x,y)] = \lg[I_i(x,y)] - \lg[F(x,y) * I_i(x,y)] \tag{4}$$

Where,i represents the category of color channel (RGB), and $F(x,y)=\lambda e^{-(x^2+y^2)/c^2}$ Represents Gaussian surround function. However, because the algorithm is difficult to maintain color fidelity[8], we use Multi-Scale Retinex(MSR).This algorithm performs Gaussian filtering on different scales and then weighted average.The formula is as follows:

$$r_{MSRi}(x,y) = \sum_{k=1}^{N} \omega_k r_{SSRi} = \lg[R_i(x,y)] = \sum_{k=1}^{N} \omega_k \{\lg[I_i(x,y)] - \lg[F(x,y) * I_i(x,y)]\} \tag{5}$$

Among them,ω_k represents the weight coefficient, and $F_k(x,y)$ represents the weight ω_k corresponds to the Gaussian surround function, and N represents the number of scales.

2.3 principle of a priori defogging algorithm for dark channel

2.3.1 optical transmission model

In computer vision, the atmospheric scattering model is shown in Figure 2, which can be expressed as:

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{6}$$

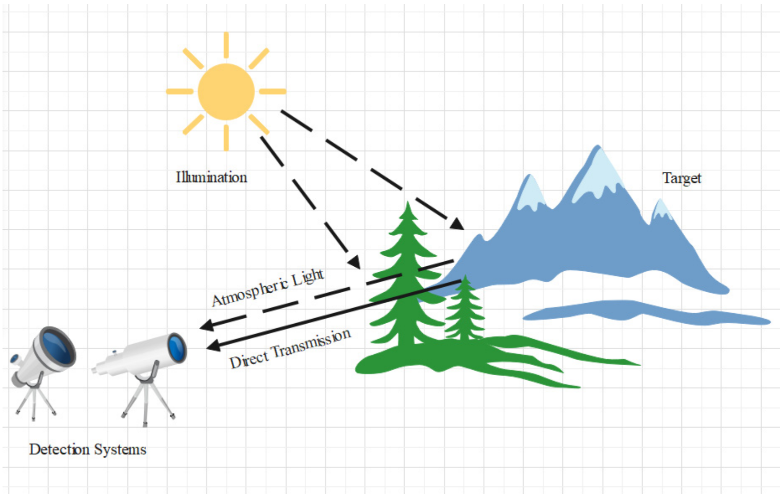

Figure 2. atmospheric scattering model

Where I(x) refers to the observed brightness, that is, the brightness obtained from the captured picture, which is a known value. J(x) is the image after defogging and restoration, that is, our goal. t(x) is the scene transmittance. A represents the global atmospheric light component. Therefore, we must reconstruct the original image by estimating atmospheric light a and scene transmittance t(x).

2.3.2 dark channel a priori

After a large number of fog free outdoor images are counted, the a priori knowledge of dark channel is introduced. Some areas always exist in images with very low intensity in at least one color(RGB)channel, which can be described as follows:

$$J^{dark}(x)=\min_{c\in\{r,g,b\},y\in\Omega(x)}(\min(J^c(y))) \tag{7}$$

Where J^c represents a color channel. c represents one of the RGB three channels. The observation results show that in the sky free region of most fog free images, there is at least one color channel in the pixel, and there is a very low brightness value, which is almost equal to 0. Therefore:

$$J^{dark}(x)\Rightarrow 0 \tag{8}$$

Normalize the imaging model, including:

$$\frac{I^c(x)}{A^c}=t(x)\frac{J^c(x)}{A^c}+1-t(x) \tag{9}$$

Since the scene transmittance t(x) is a fixed value, minimize both sides of the above formula:

$$\min\frac{I^c(y)}{A^c}=t(x)\min\frac{J^c(y)}{A^c}+1-t(x) \tag{10}$$

Since $A^C>0$, when min $J^c(y)/A^c=0$, the estimated value of the transfer function can be obtained:

$$t(x)=1-\min\frac{I^c(y)}{A^c} \tag{11}$$

In order to prevent excessive defogging and unnatural recovery, parameters are introduced θ (general) θ= 0.9), then:

$$t(x)=1-\theta\min\frac{I^c(y)}{A^c} \tag{12}$$

Therefore, by restoring the foggy image, a fogless image can be obtained:

$$J(x)=\frac{I(x)-A}{\max[t(x),t_0]}+A \tag{13}$$

Where t_0 represents the threshold set to prevent the overall white of the image caused by too small transmittance t(x).

3. image defogging system based on MATLAB

3.1 image defogging system

The defogging system uses MATLAB software as the platform for visual GUI design. The platform includes two modules: function area and image display area. The function call is realized through pull-down menu, editable text, ordinary button and coordinate area. The system is used to realize image defogging. The specific process is as follows:

1) Start MATLAB R2020a software and select ". jpg" picture to be defogged;

2) Select a picture to remove fog by clicking "open picture" in the function area of the main interface;

3) Select "defogging algorithm" to call global histogram equalization,local histogram equalization, multi-scale Retinex and dark channel a priori algorithm to defog the original foggy image; The structure diagram of the demisting system is shown in Figure 3, and its GUI main interface is shown in Figure 4.

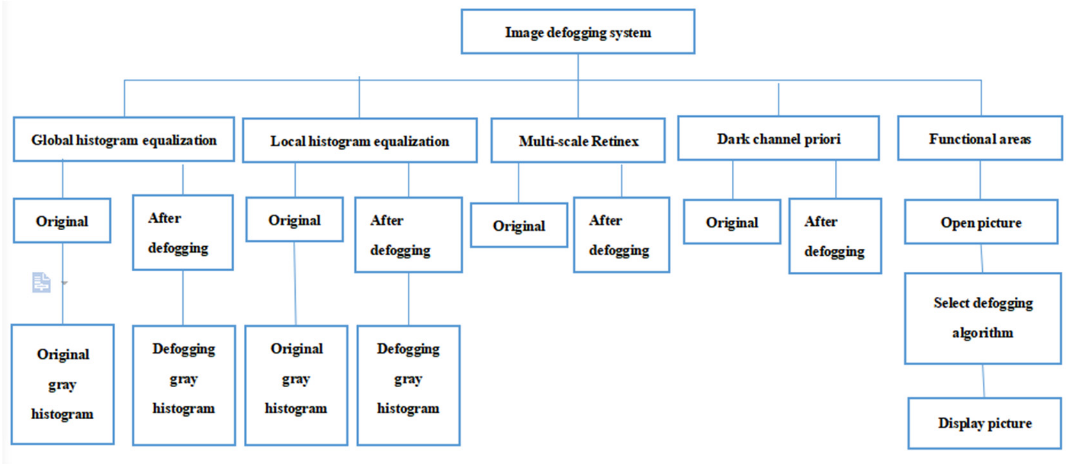

Figure 3. structure diagram of image defogging system

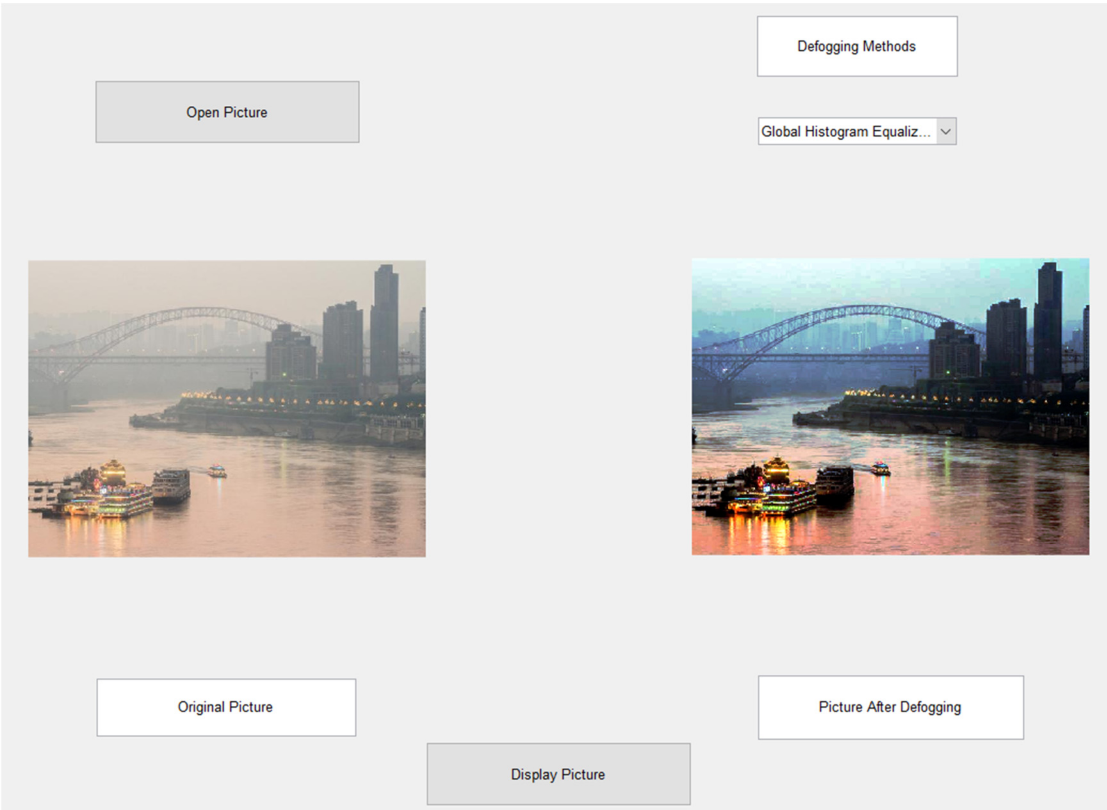

Figure 4. main interface of image defogging system

3.2 comparison of results of different defogging algorithms

Run matlab program and select different defogging algorithms. The effect of defogging are as follows.

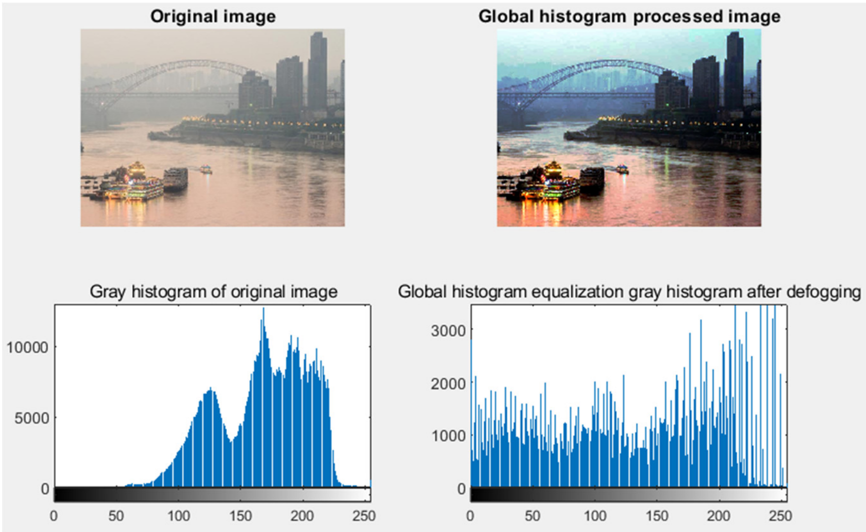

Figure 5. global histogram equalization defogging and its gray histogram

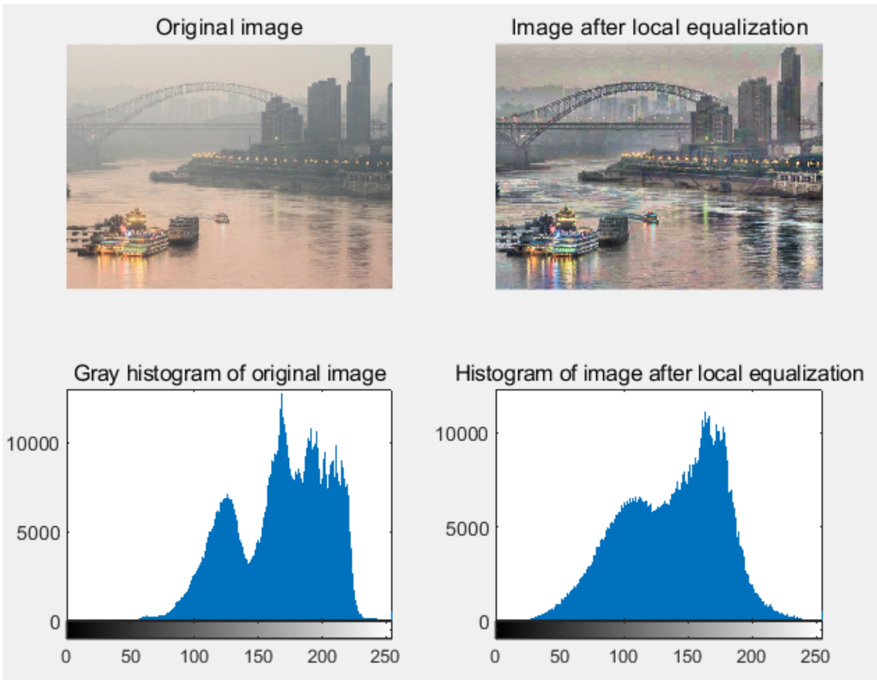

Figure 6. local histogram equalization defogging and its gray histogram

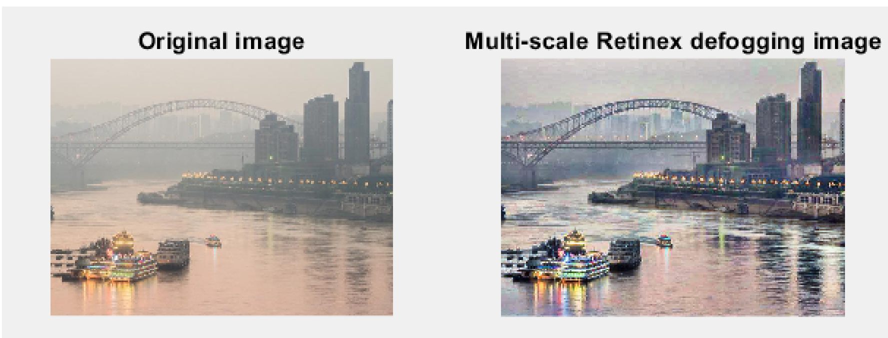

Figure 7. multi-scale retinex defogging

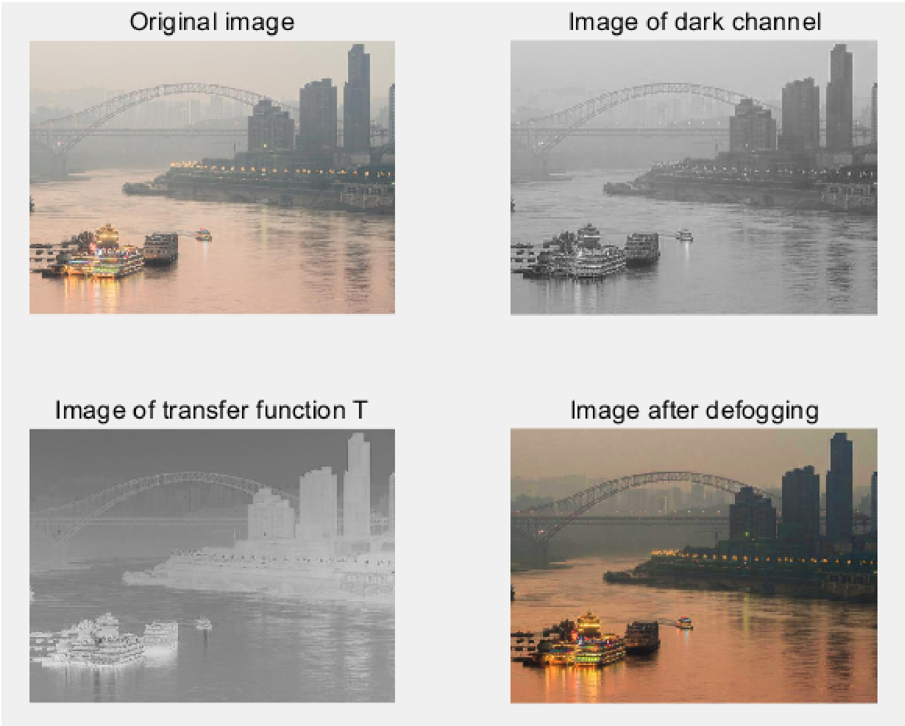

Figure 8. a priori defogging of dark channel

3.3 image quality evaluation

This paper compares different defogging algorithms in four aspects: root mean square error, signal-to-noise ratio, peak signal-to-noise ratio and running time, and evaluates the quality of the image after defogging.The root mean square error reflects the deviation between the original image and the defogging image. The greater the root mean square error, the greater the contrast and the better the defogging effect; The signal-to-noise ratio of the image is equal to the ratio of the power spectrum of the signal to the noise. The greater its value, the smaller the noise mixed in the image signal, the closer it is to the clear image and the higher the image fidelity; The peak signal-to-noise ratio is the same [9]; The shorter the running time, the higher the efficiency of the algorithm. The test results are shown in Table 1.

Table 1 performance comparison of different algorithms

Algorithm	MSE	SNR/dB	PSNR/dB	Running time/s
Global histogram equalization	3.4567e+03	9.6633	12.7442	1.031350
Local histogram equalization	1.5322e+03	13.1968	16.2778	0.860901
Multis-cale Retinex	1.2966e+03	13.9220	17.0029	0.483332
Dark channel prior	1.2732e+04	4.0010	7.0820	0.865137

According to various indicators, the four defogging algorithms have their own advantages in defogging effect. The global histogram equalization algorithm has good image enhancement effect, but the running time is long. Local histogram equalization algorithm can enhance the local details of the image, but it is also prone to local over enhancement. Multi-scale Retinex algorithm has high computational efficiency, but the color is easy to be distorted. The dark channel a priori algorithm has a good defogging effect, but it is prone to color distortion and the calculation is very complex.

4. Conclusion

The defogging system uses MATLAB software as the platform for visual GUI design. The platform includes two modules: function area and image display area. The function call is realized through pull-down menu, editable text, ordinary button and coordinate area. After our test, the global histogram equalization defogging effect is good, but the running time is long. Local histogram equalization algorithm can enhance the local details of the image, but it is also prone to local over enhancement. Multi scale Retinex algorithm has high computational efficiency, but there is still the problem of color distortion. The dark channel a priori algorithm is more natural, but it is easy to produce color distortion, and the algorithm complexity is high. At present, image defogging technology is still developing at a high speed. The disadvantage of this system is that there are few optional defogging algorithms and image evaluation indexes. Therefore, it puts forward higher requirements for us to study more comprehensive and excellent defogging algorithms in the future.

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