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Research on Road Scene Image Dehazing Method based on Improved Dark Channel Prior

Pengjie Liu[a], Han Zhang[b] and Yongfa Mi[c]
School of Shipping, Shandong Jiaotong University, Weihai 264200, China
[a]2646027724@qq.com, [b]zhanghan342215706@163.com, [c]1714417053@qq.com

Abstract

To solve the problem of road scene image defogging, a new method based on improved dark channel prior is proposed.Firstly, the atmospheric light value is estimated by an improved minimum-removing average method, and the rough transmittance is obtained by combining the dark channel prior model; then, the fine transmittance map is obtained by weighted guided filtering; and finally, a relatively rough defogging result is obtained by the dark channel prior model and the atmospheric scattering model.Then, aiming at the problems of color distortion and dark image in the result, the image brightness enhancement is carried out, and a more realistic and natural defogging result is obtained by correcting color deviation and enhancing detail information.Finally, the experiments show that the proposed method can effectively remove the fog effect in the road scene image, while maintaining the natural authenticity and details of the image, and has certain application value.

Keywords

Dark Channel Prior; Defogging; Road Scene; Color Correction; Weighted Steering Filter.

1. Introduction

With the rapid development of social economy, the popularity of cars is getting higher and higher, road traffic problems are also increasingly prominent.In road traffic, there is a large amount of fog in the road scene image due to weather or other factors, which will not only affect the driver's line of sight, lead to traffic accidents, but also affect the recognition and monitoring effect of intelligent transportation system.At the same time of standardizing drivers 'safe driving and abiding by traffic rules, it is also necessary to design and develop intelligent driving assistance system by virtue of the advantages of information technology in today's society, so as to make the automobile driving more intelligent and safe and solve the existing road traffic driving safety problems.Therefore, the research of road scene image defogging technology has important practical application value [1].

Image enhancement and image restoration are two common methods of image defogging. The former is based on non-physical model, which does not consider the reason of image degradation, but improves the visual effect of image by enhancing contrast.This kind of algorithm is widely used, but it may cause some loss or over-enhancement of the information of the salient part, and the effect is not ideal.The latter is based on the atmospheric scattering model, and then solves the fog-free image, and obtains a good image defogging effect, but it still has its limitations.Fattal et al. assumed that the transmission and the shading of the object surface are not correlated in the region, and obtained clear images by means of mathematical statistics and modeling.However, this method will fail when the information acquisition fails in specific areas of the picture.Tan's method is based on two observations: a defogged image should have a higher contrast than a fogged image, the magnitude of the atmospheric light value is based on the distance from the object to the observer, and the eye variation

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tends to be smooth.Tan's method aims to improve the visual effect of the output image by increasing the contrast ratio, but does not focus on completely restoring the fog-free appearance of the image, so this method often distorts the color of the picture.He proposed a dark channel prior method based on outdoor fog-free image statistics, which combined with atmospheric scattering model to directly estimate transmission and atmospheric light information from foggy images and then restore fog-free images.The output image of this method is natural, but there are some problems, such as high time complexity, algorithm failure for large sky area image, etc.Therefore, this paper makes corresponding improvement on the failure of dark channel first checking method in sky area [2].

2. Dark Channel Prior Defogging Principle

In the field of defogging, the atmospheric scattering model described by equation (1) has been widely used.

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

where I(x) is the image we already have (the image to be defogged), J(x) is the image to be restored without fog, A is the global atmospheric light composition, and t(x) is the transmittance.According to the definition of dark channel, in most non-sky local areas, some pixels will always have at least one color channel with a very low value.in other word, that minimum value of the light intensity of the region is a very small number.For an arbitrary input image J, the expression of the dark channel is as shown in Equation (2).

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}} J^c\,(y)\right) \tag{2}$$

where Jc represents each channel of the color image and Ω(x) represents a window centered at pixel X.From the dark channel prior theory, it can be known that the dark channel value approaches to zero for clear images in non-sky regions.i. e. formula (3).

$$J^{dark}(x) \to 0 \tag{3}$$

According to the atmospheric scattering model, the simplified equation (1) becomes equation (4).

$$\frac{I^c(x)}{A^c} = \mathrm{t(x)}\frac{\mathrm{J^c(x)}}{\mathrm{A^c}} + \left(1 - \mathrm{t(x)}\right) \tag{4}$$

Assuming that the transmissivity t(x) is constant in each window, define it as t (x), and the value of A has been given, and then perform two minimum operations on both sides of equation (7) to obtain the following equation.

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

where J is the fog-free image to be solved, according to the dark channel prior theory described above:

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

Therefore, it can be derived that:

$$\min_{y\in\Omega(x)}\left(\min_{c}\frac{J^{c}(y)}{A^{c}}\right) \rightarrow 0 \tag{7}$$

Therefore, substituting equation (7) into equation (5) yields:

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

Therefore, the estimated value of transmissivity is obtained. However, in daily life, even on a fine day without fog, there are some particles in the air, so the distant objects can still feel the influence of fog. In addition, the existence of fog makes people feel the existence of depth of field. Therefore, it is necessary to retain a certain degree of fog when defogging, so Equation (8) is modified as follows:

$$\tilde{t} = 1 - \omega \min_{y\in\Omega(x)}\left(\min_{c}\frac{J^{c}(y)}{A^{c}}\right) \tag{9}$$

In equation (9), the value of ω in this paper is taken as 0.95.

The above reasoning is based on the assumption that the global A-value is known. In practice, we can obtain this value from foggy images with the help of dark channel map. The specific steps are as follows:

Take the top 0.1% of pixels from the dark channel map according to the brightness.

In these positions, the value of the corresponding point with the highest luminance is found in the original fogged image I as the A value.

At this step, we can restore the fog-free image, and the final restoration formula is as follows:

$$J(x) = \frac{I(x) - A}{\max(t(x), t_0)} + A \tag{10}$$

The flow of the dark channel prior defogging algorithm is shown in Fig. 1, and the defogging effect is shown in Fig. 2.

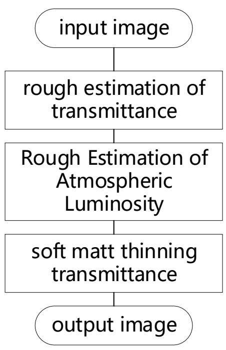

Fig 1. The flow of the dark channel prior defogging algorithm

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Fig 2. The defogging effect

3. Improved Dark Channel Dehazing Algorithm

3.1 Improved Method for Estimating Atmospheric Light Value

When there are other bright light sources (such as street lamps, car lights, large areas of reflected water surface, etc.) in the outdoor foggy image, the algorithm of selecting the brightest region sometimes regards these light sources as atmospheric light, which leads to the atmospheric light value being higher than the true value.In order to eliminate the estimation error caused by dark channel prior theory, this paper chooses to slightly expand the range of selected values and take the average value to reduce the error, that is, select the first 0.3% part in the pixel value, in the final data, in order to reduce the error, use the method of removing the average value of the maximum value and the minimum value, and then take the average value of the remaining data as the atmospheric light value.

3.2 Transmittance Optimization Method

Because the initial transmissivity is not acquired accurately enough, the white edge effect exists, and the traditional method usually uses a soft matting method to further refine the initial transmissivity. Although this method can improve the precision of the transmissivity better, the processing process needs to calculate Laplace equation, which causes the algorithm to occupy a large amount of processing time and memory space, and cannot meet the real-time performance required by actual defogging.In order to solve this problem, in recent years, the guided filtering method is usually used to refine the transmittance. Guided filtering is an algorithm based on image filtering. Through a guide map, the image to be processed (i.e. input image) is preprocessed by filtering technology, and the final output image is generally similar to the target image.In this paper, the weighted steering filter is used to refine the transmittance. The weighted steering filter is an optimization algorithm of the steering filter and can achieve better results than the steering filter.

Weighted directed filtering is an image filtering algorithm based on local linear model, which can be widely used in image denoising, image enhancement and edge preservation.Its principle can be summarized as follows: by weighted average of the neighborhood around the pixel, the image is smoothed and the edge information of the image is retained.In the process of weighted average, the weight of each pixel is calculated according to its similarity with the target pixel.The similarity is usually calculated by Gaussian weighting function or cosine distance.Specifically, for each pixel point in the image, the weighted guided filtering algorithm performs weighted average on the surrounding pixel points according to a certain weight, and uses the weighted average result as the output value of the current pixel point.The weight is calculated according to the similarity between the pixels, and the similarity is usually calculated by using a Gaussian weighting function or a cosine distance.

The algorithm flow of weighted steering filtering is as follows:

(1) For each pixel, define a local linear model, that is, in the neighborhood of the pixel, assume that the relationship between pixels can be represented by a linear model.

(2) Calculate the weight of each pixel according to the similarity between pixels, usually using Gaussian weighting function or cosine distance.

(3) For each pixel point, the pixel points in its neighborhood are weighted and averaged according to the weight to obtain the output value of the current pixel point.

Repeat the above steps until all pixel points of the whole image are processed.

Weighted directed filtering algorithm can be applied to many image processing tasks, such as image denoising, image enhancement and edge preservation.The main advantage of the algorithm is that it can realize image smoothing while preserving image details and edge information, and the computational complexity of the algorithm is relatively low, so it is suitable for real-time processing and other scenes.

3.3 Image Brightness Enhancement

Using weighted steering filter to correct the transmittance may make the restored defogged image darker.In order to obtain better visual effect, it is necessary to improve the overall brightness of the defogged image.In this paper, the R, G, B components of the restored defogged image J(x) are transformed into H, S, I components by using the transformation from RGB model to HIS model. Here, only the brightness I is enhanced, and then the new H, S, I components are transformed into R, G, B components by using the transformation from HIS model to RGB model, and the final clear defogged image can be obtained.

Fig. 3 is a graph showing the results of the experiment. The first column of the first row is the foggy original image, the second column of the first row is the dark channel image, the first column of the second row is the transmittance image obtained by the original algorithm processing, and the second column of the second row is the transmittance image after the weighted steering filter improvement processing.The first column of the third row is the result graph obtained by the original algorithm, and the second column of the third row is the result graph obtained by the improved processing.As shown in the figure, the improved transmittance map is finer than that obtained by the original algorithm.

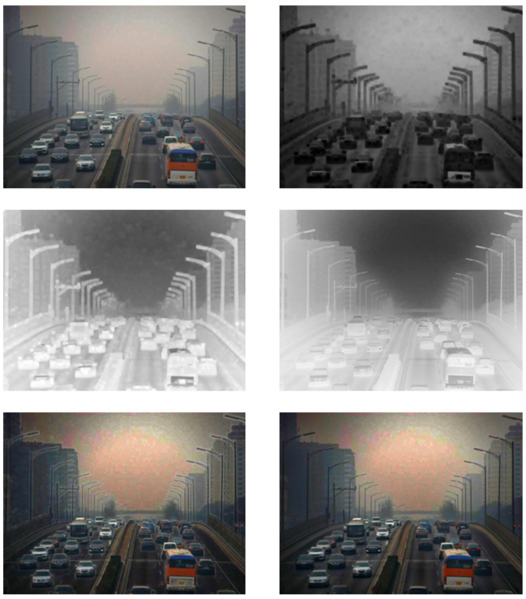

Fig 3. A graph showing the results of the experiment

4. Simulation Experiment and Analysis

It can be seen from the above figure that compared with the dark channel prior method, the fog-free image restored by the method in this paper is more realistic in color, richer in details and clearer in

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structure. At the same time, the transmittance map of the proposed method is smoother than that of the dark channel prior method.

In order to evaluate the effect of defogging objectively, the peak signal-to-noise ratio (PSNR) is used.PSNR is the most widely used objective image evaluation standard, and its value depends on the error between the corresponding pixels of the original fog image and the restored image, that is, PSNR is sensitive to the error, and the larger its value is, the smaller the image distortion is [3].The PSNR is defined as follows:

$$PSNR = 10\log_{10}\frac{(2^n-1)^2}{MSE} \tag{11}$$

where n is the number of bits per pixel, and generally, n of a grayscale image is 8, that is, the number of grayscale levels is 256.The MSE is defined as follows:

$$MSE = \frac{1}{h \times w}\sum_{i=1}^{h}\sum_{j=1}^{w}(I(i,j)-J(i,j))^2 \tag{12}$$

where h is the height of the image, ω is the width of the image,(i, j) is the pixel coordinate, I (i, j) is the initial foggy image, and J (i, j) is the restored fog-free image.The MSE represents a mean square error between the original fog image and the restored fog-free image, and the smaller the MSE value is, the higher the definition of the restored fog-free image is, and the larger the PSNR value is.

Table 1. PSNR Comparison Results

Numble	original algorithm	algorithm in this paper
1	21.0699	25. 3688
2	20. 1673	26. 3412
3	22. 3655	25. 1246
4	22. 1756	24. 2145

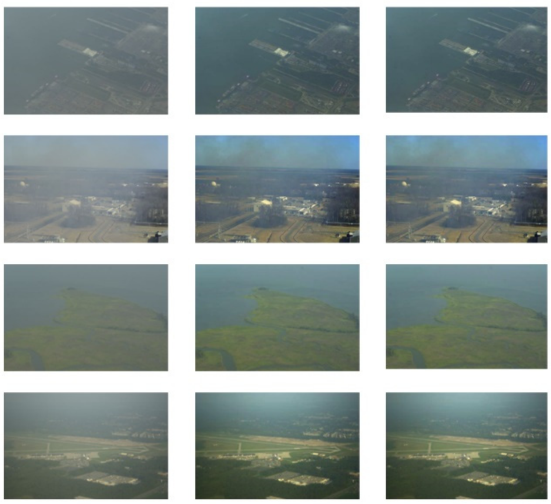

Fig 4. A picture effect comparison of this experiment

It can be found from the experimental data in the Table 1 that the PSNR data obtained by the algorithm proposed in this paper are greater than those obtained by the original algorithm, indicating that the image distortion is small and the clarity and newness are good.Experimental results show that the proposed algorithm can effectively improve the definition of defogged images and enhance the visual experience.

Fig. 4 is a picture effect comparison of this experiment, in which the left column is a fogged picture, the middle column is a defogged image obtained by the original algorithm, and the right column is a defogged image obtained by the algorithm in this paper.

5. Concluding Remarks

The dark channel prior defogging algorithm based on the basis guided filter can obtain clear and true color fog-free images.However, the transmittance obtained by this method is not smooth in the same depth of field, and contains a lot of details, so it is not accurate enough.In this paper, the atmospheric light value estimation and weighted guided filtering method can be combined to obtain an ideal transmittance map, so that the optimized transmittance is smooth and accurate, and the defogging effect is also improved to a certain extent. Finally, the overall brightness of the image is enhanced by using the mutual conversion between RGB model and HIS model, and the final clear image without fog is obtained.This is of great significance to the future research of computer vision and object detection.

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