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A Fast Video Haze Removal Algorithm Via Dark Channel Prior

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Abstract

The existed-algorithms has a poor real-time performance, and need high-configuration device to implement, in term of high-resolution video.For resolving above problems, this paper presents a fast video haze removal algorithm base on dark channel prior to improve the performance of algorithm. The dark-channel-prior-based haze removal algorithm, the imaging model in fog weather and the optimizing transmissivity are important technical support. Fast video haze removal algorithm firstly, uses guided filtering technology, which fix the problem of massive RAM storage, replace the soft matting approach. Then, it explores that the methods of down sampling and interpolation to measure the transmissivity, which can decline the time on images defogging. compared with the algorithm of MSRCR. Finally, the experimental results show that the improved algorithm our proposed can improve the speed of video defogging, and reduce the cost of equipment on image and video processing.

*Keywords:*Dark channel prior, guided filtering, video defogging;

1. Introduction

There are two kinds of recovery methods for fog-degraded image[1] so far,the one is image enhancement ,and the other is image restoration. The method based on image enhancement has a wide range of applications, but the recovery effect of the protruding part in the foggy images is poor. The model of the recovery method based on the physical is well-target, get the image more natural. It has a number of image restoration method at this stage , the representative is image haze removal algorithm via the dark channel prior.He[2] and other scholars proposed a images defogging method based on the dark channel prior ,it has already obtain a natural de-fog image,however,the

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space complexity and time complexity of the whole algorithm is high, and the configuration requirements for the device are also high, with poor real-time performance ,which affects its applications in many fields .In this paper, we present a fast video haze removal algorithm, based on the dark channel prior.

2. The model of atmospheric scattering

At this stage, the model of atmospheric scattering is proposed by Mc Cartney is generally used to study in the field of image processing. Mc Cartney model[3] divides the light that device received into two parts, attenuation model and atmospheric light model. The above two models must appear simultaneously in the acquisition of images. The model of atmospheric scattering is applied to images defogging research,the formula is described as below:

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

In the formula (1), I is the fog-degraded image; x is the space position of pixel in the image; J is the clear image after defogging; t is the transmissivity graph in the current scene; A is the value of current atmospheric atmospheric ; $J(x)\cdot t(x)$ is the part of the scene where the clear object arrives at the image capturing device after attenuation through the transmission medium. $A(1-t(x))$ is the effect of atmospheric light on the imaging. The goal of defogging is getting J, A, t from I.From the formula (1) can be obtained image $J(x)$ after the fog is remove:

$$J(x) = \frac{I(x) - A}{t(x)} + A \tag{2}$$

3. Haze removal algorithm via dark channel prior

3.1. The law of dark channel prior

The theory of dark channel prior[4] is the law summed up by Kaiming He and other scientists. Futhermore, a single images defogging method based on this theory is proposed. The theory of dark channel prior is obtained through outdoor images statistics when sunny weather . By counting a large number of outdoor clear images without fog, it was found that there was at least one color channel in the small domain of the non-sky region, and its intensity was extremely low. That image dark channel can be expressed as:

$$J^{dark}(x) = \min_{c\in\{r,g,b\}} (\min_{y\in\Omega(x)} (J^c(y))) \approx 0 \tag{3}$$

J^c indicates the three channels of the input image J;And $\Omega(x)$ is a small x as the center of the area, also known as the window;J^{dark} is the dark channel for image J;The value of $J^{dark}(x)$ has been very small or even close to 0. x denotes the coordinate position of the pixel in the image; y is the position of the pixel in the small area;The idea of the dark channel prior to solve the unknown parameter from the atmospheric scattering model and restore the clear image.

3.2. Estimated the value of atmospheric light and transmissivity

In the conventional single images defogging algorithm, the most common way to obtain the value of atmospheric light A is according to an opaque foggy region. For some foggy images ,the maximum brightness pixels in the scene may appear in the white building and other places where the brightness. The He's algorithm can not accurately estimate the A value for an image, when it contains a large number of white regions. In this paper, the estimation process for A is as follows:

$$\mathrm{I}^{dark} = \min_{c\in\{r,g,b\}} (I^c(x)) \tag{4}$$

Finding the brightest pixels at I^{dark}, choicing the corresponding position of the video frame after the sampling as the center, make the maximum filtering for the radius of 1/30 line, and selecting the maximum value in the RGB three channel as the atmospheric light value A in the maximum position.

The transmissivity represents the characteristics of light when it is propagating in the atmosphere. This paper suppose the atmosphere is uniform, the scattering coefficient β in the whole image is a fixed-value.On the each of image,the degree of degradation is mainly determined by the distance of light transmission or called scene depth .Combining the knowledge of dark channel prior and the atmospherics cattering models, it can estimate the fog concentration at the time of shooting and calculate the transmissivity t. At the formula (1) ,seeking the minimum operation both sides can obtain formula (5):

$$\tilde{t}(x) = \frac{1-\min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)} \mathrm{I}^c(y)/A))}{1-\min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)} \mathrm{J}^c(y)/A))} \tag{5}$$

Put the formula (3) into (5), and the size of $\Omega(x)$ is chosen to be 1 x 1:

$$\tilde{t}(x) = 1 - I^{dark}(x)/A \tag{6}$$

Due to the existence of fog, let people feel the depth of information. So, if the fog removed completely clean, This image is unscientific, will be affect the perception also. A constant ω ($0<\omega \leqslant 1$) is added to formula (5), which keep some fog of distant scenes. In this paper, $\omega = 0.85$. We can btain formula (7) as below:

$$\tilde{\mathrm{t}}(\mathrm{x}) = 1 - \omega \times (I^{dark}(x)/A) \tag{7}$$

4. Haze removal algorithm via dark channel prior

4.1. Guided filtering to optimize transmissivity

The algorithm of dark channel prior has been paid attention by a large number of scholars since it was put forward.Especially, in the field of image processing, due to its huge amount of computation, it is difficult to be widely used in practice. The main reason of its inefficiency based on the complexity of the soft matting algorithm, the use of soft matting to optimize the process of transmissivity, and achieved very fine results.However the complexity of this method is particularly high, the cost of RAM storage is also too large. Therefore this paper selected a new filter: guided filter[5] . The performance of guided filtering is similar to the soft matting, but its filtering is faster. The filtering model of guided filter is given by:

$$q_i = \sum_j w_{ij}(I)\, p_j \tag{8}$$

In formula (8), i, j are the coordinates of pixels; I is the guiding graph of guided filtering; P is the image to be filtered; q is the filtered image; w_{ij} is a function of the guided graph, called the filter kernel. In the local region with k as the center in the guidance graph I, suppose that the q is related to the filtered image:

$$q_i = a_k I_i + b_{k,} \forall i \in \omega_k \tag{9}$$

The linear coefficient a_k, b_k constant in the k region. The purpose of the guided filter is to find a set of linear coefficient a_k, b_k which can make the input graph p similar to the output graph q.

Through the calculation and comparison, the algorithm greatly reduces the cost of RAM storage by using of guided filter.This defect will be dispeled, using 2G RAM storage device processing images will also very easy.

4.2. Downsampling and interpolation

The guided filter optimization of transmissivity compare with other filtering algorithms can get more sophisticated results, but its calculation speed can not reach the practical needs. If you can lose a bit of accuracy within a reasonable range,it will not have large influence on the results of the images defogging. Then consider the transmissivity, this paper not directly operation of the input image, instead,it firstly shrink the input image, such as, shrink it to the original size of 1/6, and then calculates the image after the operation of the transmissivity. After the input image is shrinked, the original size of the transmissivity is obtained by the interpolation algorithm should also can achieve good results. There are three interpolation algorithms commonly used in the image processing: the nearest neighbor interpolation, the bilinear interpolation[6], the cubic interpolation method.

Cubic interpolation method, in some specific occasions, the smooth effect of bilinear interpolation will make the details of the image loss, through the high-order interpolation can compensate for the details of the bilinear interpolation loss, high-order interpolation commonly used to achieve convolution, the value of the output pixel is the weighted average of the pixel values of the sampling points in the nearest 4 × 4 neighborhood of the input image.The cubic interpolation method is a polynomial interpolation method. The method uses the cubic polynomial $S(x)$ to approximate the optimal interpolation function sin $(x) / x$, and its mathematical expression is:

$$\begin{cases} 1 - 2|x|^{2|} + |x|^3, 0 \leq 1 \\ 4 - 8|x| + 5|x|^2 - |x|^3, 1 < |x| < 2 \\ 0, |x| \geq 2 \end{cases} \tag{10}$$

In this paper, we analysis the advantages and disadvantages of three classical methods. In Fig.1,show the original image,and after three methods of processing. Firstly, we shrink the size of a sample with a resolution of 600×450 to 1/6, and then use the the cubic interpolation method to blown up the image by 6 times. Respectively, time consuming is 10ms, 16ms, 20ms. The date show the cost of the time is almost similar, but the method of the cubic interpolation method is the most clearly , other methods are blurred.

a **b** **c** **d**

Fig. 1. Renderings of three interpolation (a) first picturethe original image; (b)the nearest neighbor interpolation;(c) the bilinear interpolation; (d)the cubic interpolation.

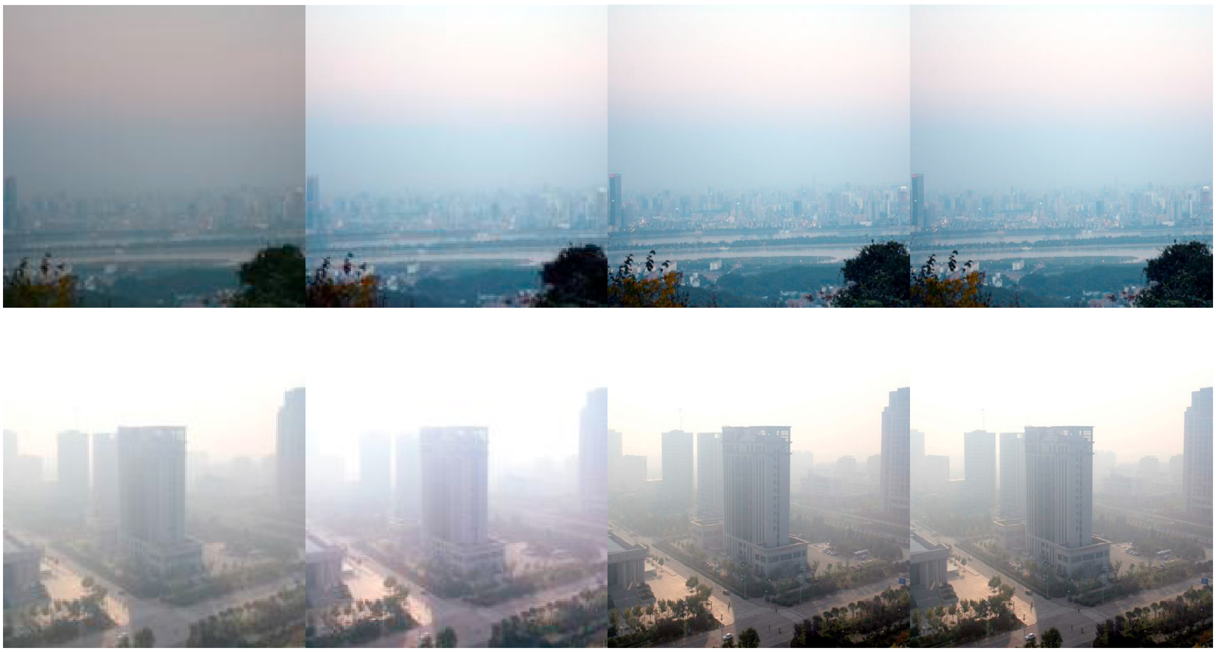
When the transmissivity is obtained, the input image is first shrinked, and then the transmissivity of the small image is obtained, and the defogging renderings of the transmissivity of the original size is obtained by the interpolation algorithm. Through the naked eye observation, can't find the obvious difference, but for the speed, used shrinked method has been significantly improved, the algorithm we propose can greatly enhance the real-time performance of haze removal dark channel prior, so that the algorithm can be applyed in more multi-application scenarios, greatly improving the user experience. The Table 1 shows the time-consuming situation for different resolutions and different scaling ratios I.

Table 1.The time spent on the different resolution of the image at different magnifications （Unit：ms）.

I	0.2	0.4	0.6	0.8	1.0
600*450	14.82	26.96	39.23	65.36	100.36
1024*768	35.99	58.36	119.63	210.69	290.69

5. Experimental results and analysis

In this paper, the experimental hardware parameters are: Core i3 processor, 2GB DDR3 memory, the operating system for the windows 7; simulation software: Microsoft Visual Studio 2010 (Open CV 2.4.11). Three different images were tested by this algorithm, and compared with MSRCR and He's algorithm. The defogging effect is shown in Fig.2. The first column is the original image, the second column is defogging effect through the MSRCR algorithm, the third column is effect of He's algorithm and the fourth column is the defogging effect of this paper.



a b c d

Fig. 2. Renderings of three different methods (a) original image ; (b)MSRCR ;(c) He ; (d)this paper.

For the subjective vision, the defogging effect of this algorithm is more natural, and there is no color distortion in the large area of the sky, while the defogging effect of the MSRCR algorithm is rather white, but the He's algorithm is better than the treatment in this paper.

For the objective quality evaluation, this paper compares the quality of different image de-fog algorithms by the two image evaluation criteria of average gradient and information entropy[7,8]. The average gradient reflects the detail definition of the image, and the bigger the average gradient is, the clearer the detail is. Information entropy reflects the richness of image information. The greater the image entropy is, the richer the amount of information is, the better the quality is.

Table 2.The mean gradient contrast of three algorithms

image	original image	MSRCR	He	this paper
image a	5.8563	4.5689	8.4575	7.8541
image b	1.6684	1.9866	3.4699	2.6899
image c	3.2589	3.5687	5.5469	4.9875

Table 3.Comparison of information entropy between three algorithms

image	original image	MSRCR	He	this paper
image a	13.5698	14.2665	15.3698	15.2568
image b	10.3669	11.3698	12.6989	11.9869
image c	9.6999	9.8769	11.3699	10.9875

Table 4.Comparison of processing time of three algorithms（Unit：s）

image	original image	MSRCR	He	this paper
image a	540*600	1.5769	46.7896	0.0477
image b	540*860	2.7865	69.3697	0.0639
image c	960*1024	3.8694	109.6599	0.0988

Through analysing the date from Table 2 and Table 3, we can find that the average gradient and information entropy of the image both improved after three kinds of algorithms . The effect of MSRCR algorithm is not particularly obvious, the He's algorithm has the best effect, and the algorithm on this paper is similar with the He's algorithm.From Table 4,we can find that this paper's processing time is short than the other two algorithms, greatly reducing the processing time.

For the video of the fog haze weather,this paper select the region of Beijing as the test video. We use frame-by-frame processing. The video a total of 480 frames, and it's playback time is 20.0s at 24fps , the size of each frame is 540* 600.For the video processing effect, the video image color recovery natural and clear in the sky area and it does not appear color distortion. The entire continuous video is subjected to frame-by-frame processing at a rate of 24.8 frames per second.

6. Conclusions

This paper presents a fast video haze removal algorithm which combined dark channel prior and atmospheric scattering model to improve the efficiency and effect of video fogging. However, in high-resolution video, the processing speed can not reach the time of human eye resolution, and fully reach the requirements of most of the practice, we need to make further research on high-resolution images of the defogging method. In addition, on the video frame we are interested in the part of the targeted treatment, it also have practical value, which is the point we needs to improve in our future working and learning.

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