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Dehazing Image by Local Extrema

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ABSTRACT: Poor visibility becomes a major problem for most outdoor vision applications. Bad weather, such as fog and mist, can significantly degrade the visibility of scene. The low visibility inevitability handicaps visual recognition and comprehension. The goal defogging methods is to remove the effects of fog and recover details and colours of scene from foggy image. most traditional image improvement methods , such as histogram equalization, retinex ,the wavelet transform ,usually cannot obtain ideal defogging result .These methods mainly focus on enhancing low brightness and low contrast features in digital images , and they are simple, efficient, and can be applied to most real time scenes. Atmospheric conditions induced by suspended particles, such as fog and mist, severely alter the scene appearance. In this paper, a novel defogging method based on the local extrema, aiming at improving the image visibility under foggy or hazy weather condition. The proposed method utilizes atmospheric scattering model to realize the fog removal. It applies the local extrema method to figure out three pyramid levels to estimate atmospheric covering, and manipulate the tone and contrast of details at different scales through multi scale tone manipulation algorithm . The results on the experiments of comparison with traditional methods demonstrate that the proposed method can achieve more accurate restoration for the colour and details, resulting in a great improvement in image visibility. The existing method is mist image model and dark channel prior model these methods have some disadvantages. Therefore a new method is proposed. This method utilizes atmospheric scattering model to realize the fog removal. It applies the local extrema method.

KEYWORDS: Defog, local extrema, atmospheric scattering model, haze removal.

I. INTRODUCTION

Under bad weather conditions, such as fog, haze, and smoke, light from objects is absorbed and scattered by atmospheric particles, and images acquired in outdoor are often degraded [1]and show poor visibility and low contrast. Unfortunately, in many outdoor vision applications, such as intelligent vehicle, surveillance, autonomous navigation, object tracking, and remote-sensing systems,[2-3] it is assumed that images have clear visibility and high contrast. Basic feature detection algorithms, including interest point detectors and edges detectors, are sometimes inevitable procedures in the above-mentioned applications. These algorithms will exhibit poor performance when they process low-contrast images. A large number of clear features are necessary and helpful for satisfactory subsequent processing results. Hence, increasing contrast of degraded images is important, and it helps in finding more distinct local features (e.g., interest points and edges) from haze images.

Fine haze removal[4] methods are expected to satisfy the following requirements. For photography , haze removal results should present clear visibility to satisfy human vision. For many computer vision applications, the results are required to possess high contrast to benefit subsequent processing procedures, for example, feature detection. In some particular computer vision systems, the haze removal methods are required to be simple enough to achieve real-time computation. Besides, it is advised that haze removal methods use only a single input image.

Some general contrast enhancement techniques have the ability to increase the visibility of haze images, such as histogram equalization, gamma correction, logarithmic image processing, and so on. Since the haze effect changes exponentially in the distance of scenes from observers, scene points at different depth layers are affected by different haze effects. These traditional methods enhance the contrast of haze images using only intensity value of pixels. They ignore the spatial distribution information of haze, which is related to the depth map of scene. Thus, these methods are inadequate in removing the haze effect.[5].

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II. BACKGROUND

Atmospheric conditions[6] induced by suspended particles, such as fog and haze, severely alter the scene appearance. Restoring the true scene appearance from a single observation made in such bad weather conditions remains a challenging task due to the inherent ambiguity that arises in the image formation process. In this paper, we introduce a novel Bayesian[7] probabilistic method that jointly estimates the scene albedo and depth from a single foggy image by fully leveraging their latent statistical structures. Our key idea is to model the image with a factorial Markov random field in which the scene albedo and depth are two statistically independent latent layers and to jointly estimate them. We show that we may exploit natural image and depth statistics as priors on these hidden layers and estimate the scene albedo and depth with a canonical expectation maximization algorithm[8] with alternating minimization .We experimentally evaluate the effectiveness of our method on a number of synthetic and real foggy images. The results demonstrate that the method achieves accurate factorization even on challenging scenes for past methods that only constrain and estimate one of the latent variables.

III. DEFOGGING METHODES

A. SKYLIGHT ESTIMATION AND WHITE BALANCE

Skylight *A* is typically assumed to be a global constant. We estimate *A* through the method based on the dark channel prior. The dark channel of input image can be defined as

$$I_{dark}(x, y) = \min_{(x;y)2\tilde{A}} \left(\min_{c2fR;G;Bg} I_c(x; y) \right); \quad (1)$$

where *Ic*(*x, y*) is a color channel of *I*(*x; y*) and $\tilde{A}$ is a local patch. In order to solve *A*, we choose the 0*:*1% brightest pixels of the dark channel as their preferred region and define
\these pixels as *I*0*:*1%. Then, the average value of *I*0*:*1% in the input foggy image is selected as the initial skylight, i.e. ,*A* mean = mean(*I*0*:*1%)

The color of foggy image sometimes suffers from illumination variations. For example, the foggy day is often accompanied by cloudy weather which causes the scene to be prone to partial color. Therefore, to improve the sky light estimation, we will correct fog to be pure white. The calculation can be performed as

$$A = A^{c}_{mean} / \max(A^{c}_{mean})_{c2R;G;B} \quad (2)$$

where *A* is the ideal skylight estimation result. means setting *A* mean to be (1,1,1). Then, we can obtain the corrected image *I0* after white balance, which can be inferred as

$$I'(x; y) = I(x; y) / A \quad (3)$$

B. COARSE ESTIMATION OF ATMOSPHERIC VEIL

From above equations we can find the atmospheric veil estimation becomes the key step to calculate the restored image *R*. Due to its physical properties, the atmospheric veil is subject to two constraints: i) 0 · *V* (*x; y*) · 1, and ii) *V* (*x; y*) is not higher than the minimal component of *I0*(*x; y*). We thus take the min operation among three color channels and acquire a rough estimation of the atmospheric veil:

$$\sim V(x; y) = \min_{c2fR;G;Bg}(I'c(x; y)) \quad (4)$$

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where ~ *V* is the coarse estimation matrix of atmospheric veil. For the gray image, it is expressed as ~ *V* (*x; y*) = *I0*(*x; y*). Atmospheric veil coarse estimation is equivalent to the minimum filtering, but a single minimum filtering usually causes obvious halo or block artifacts. In order to obtain more accurate result, we need reasonable constraint manipulation to further refine~ *V* .

C. IMAGE RESTORATION BY LOCAL EXTREMA

Atmospheric veil depends solely on the depth of the objects and has nothing to do with scene albedo.[8] The scene depth is changing smoothly across small neighboring areas except at the edges. Therefore, the refinement of atmospheric veil can be considered a smoothing problem. In this paper, in order to generate an ideal estimation of the atmospheric veil, we apply an edge-preserving smoothing approach based on the local extrema for refinement. Our method based local extrema is inspired from Subr stechnique, [9]which uses edge-aware interpolation to compute envelopes. A smoothed mean layer is obtained by averaging the envelopes. The method can extract fine-scale detail regardless of contrast. However, single mean layer is not sufficient to well approximate atmospheric veil, and it is solved by iterative calculation, which is time-consuming. Our non-iterative method consists of three steps: 1) identification of local extrema[10] of ~ *V* ; 2) inference of extremal envelopes; 3) visibility enhancement of the result by multi scale tone manipulation algorithm. First, we locate the extrema in ~ *V* . Pixel *p* is considered as a maxima if at most *k*¡1 elements in the *k*£*k* neighborhood around *p* are greater than the value at pixel *p*. In the same way we can locate the minima. Image details whose extrema are detected by using a *k* £ *k* kernel have wavelengths of at least *k*=2 pixels. We choose *k* = 5 as the size of the extrema location kernel[11] in this paper.

As for the next step, we will employ the interpolation of the local minima and maxima to compute minimal and maximal extremal envelopes respectively. Let *S* be the pixel set of local extrema,[12] we compute an extremal envelope *E* using an interpolation technique proposed by Levin et al. for image colorization. It assumes that the *E* is a linear function of the ~ *V* , and seeks an interpolant *E* such that neighboring pixels *E*(*r*) and *E*(*s*) have similar values if ~ *V* (*r*) and ~ *V* (*s*) are similar.

IV. COMPARISON

In order to verify the effectiveness of the defogging method, [13]we will evaluate the proposed method on the real sceneand the virtual scene. The experiments will be conducted on the matlab platform and mainly deal with low resolution images for better detail comparison. Firstly, in the aspect of restoring real world foggy images, our method will compare with two classical methods:[14]

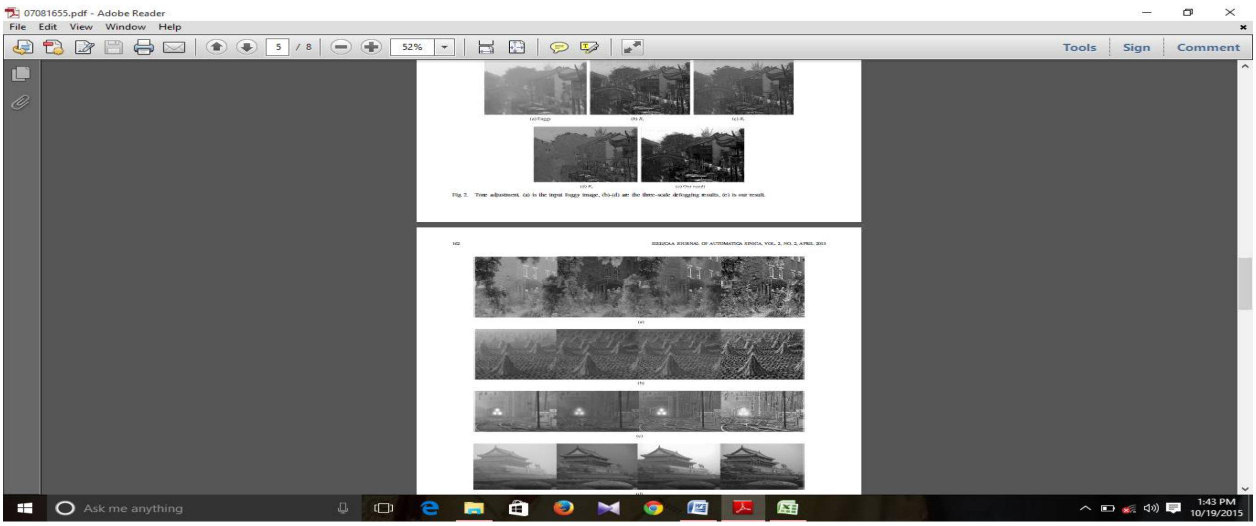

Fig.1: Tone adjustment and fog removal result real images

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In fig.1 Tarel*0*s[15] no black-pixel constraint and He*0*s[16] method based on guided filter introduced a complete inference of atmospheric veil in. He et al first proposed dark channel prior to initialize transmission estimation in However, the matting Laplacian [17]regularization might lead to an overall reduction of contrast at the distant regions and had high time and space complexity. Reference was their improved method free from these problems. Both methods are known for their robustness and can produce visually pleasing restored results. The time consumption of is mainly associated with the estimation of transmission map or atmospheric veil. Both of their calculations can reach (ON).

Three methods have strong defogging ability. Some objects which were barely[18] visible in foggy image appear clearly in enhanced images. However, Tarel*0*s[11] results have lower contrast and prone to be saturated; He*0*s[16] method has a good ability of fog removal, but its detail enhancement ability is limited. Compared with the two methods, our method can better restore image and achieve much greater color consistency. Experimental results also show that proposed method has a obvious superiority in preserving detail and can avoid the halo effect. In order to objectively assess these methods, we use the assessment method dedicated for visibility restoration proposed in . This method computes two indicators *e*, ^{1}r [10]to assess the performances of a contrast restoration method through comparing two gray level images: the input image and the restored image. The value of *e*[10] evaluates the ability of the method to restore edges which were not visible in the input image but are in the restored image. Te value of ^{1}r expresses the average visibility effect enhanced by the restoration method.[9]

Furthermore, a good image restoration method should also make the restored image look natural and real, therefore, color retention degree is an important index for evaluating the defogging methods, which is denoted as *h*. We evaluate the color retention ability by histogram comparison. The more similar the histogram shapes, the stronger color retention ability is. We use the color histogram intersection method to calculate the histogram[7] similarity between original image and the restored image, which is expressed as a percentage. We use the edge preserved index (EPI) *s*[5] to measure the edge-preserving ability, which is obtained by calculating the ratio value of gradient-sum of pixels in the original image and restored image.

In the next experiments, we employ the database named for the evaluation of the proposed method under the ideal condition. is available for research purpose and in particular to allow other researchers to rate their visibility enhancement methods. This database provides 6 images of the same virtual scene with and without fog. The proposed method will be compared with 5 other methods multi-scale retinex (MSR), adaptive histogram equalization, free space segmentation, no black-pixel constraint and dark channel prior. To quantitatively assess those methods, we use the method of computing the average absolute error *Eavg* between the image without fog and the enhanced image.

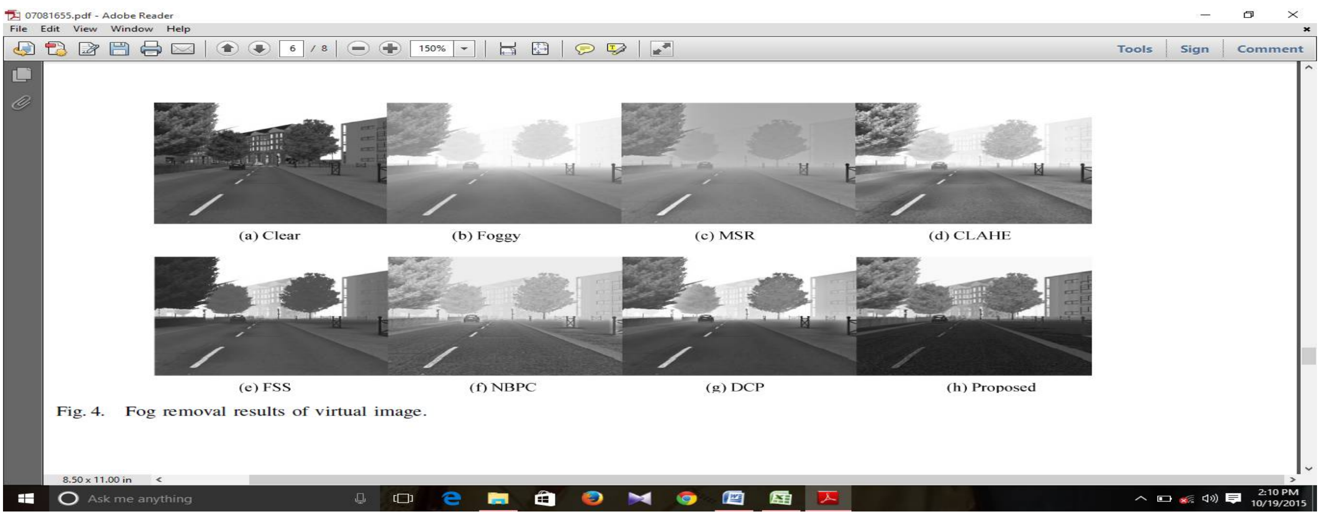

Fig. 2: Fog removal results of virtual image

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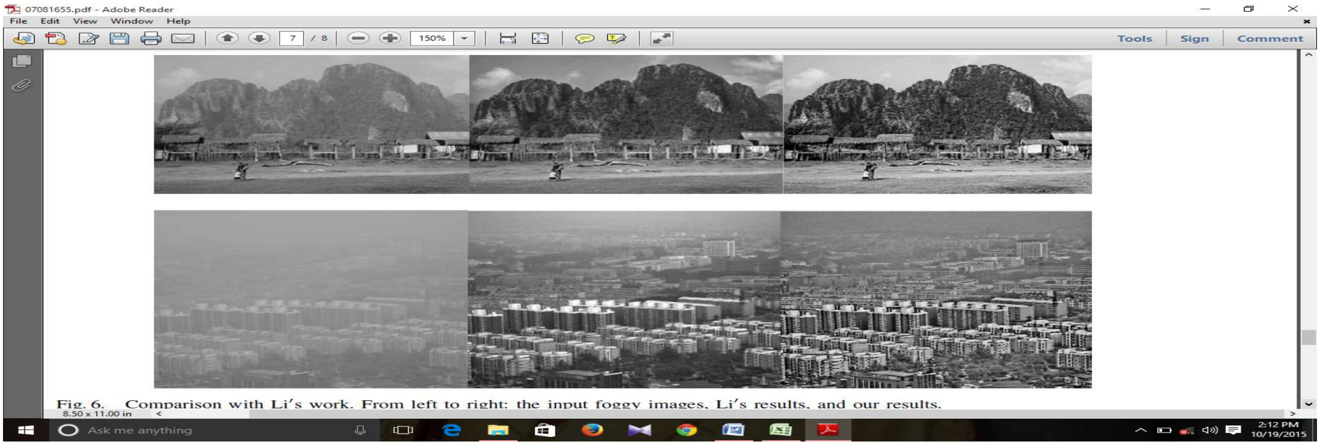

Fig.3: Comparison with Li;s work

Fig. 4: Comparison with Caraffaos work. From left to right: the input foggy images, Caraffaos results, and our results.

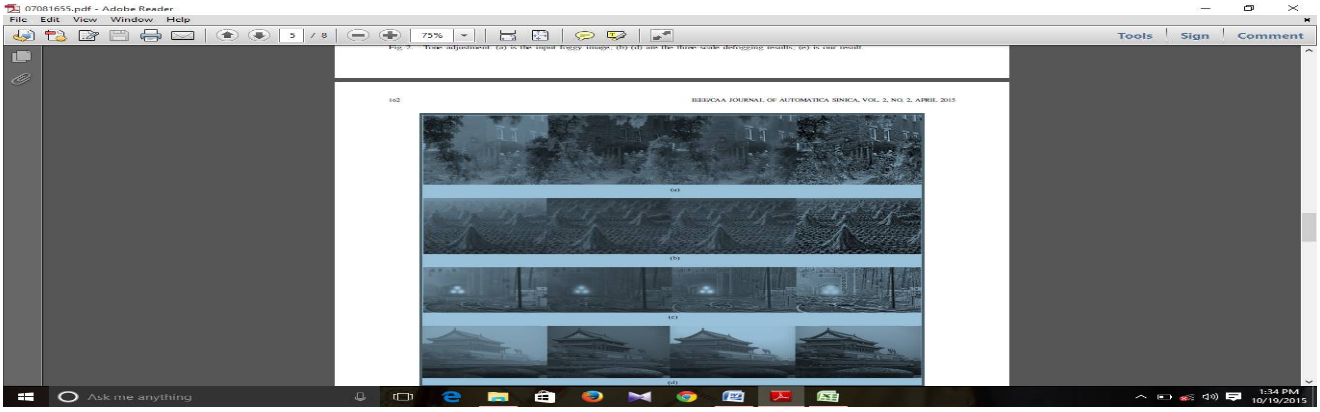

Fig.5: Fog removal result for real world image.From left to right the input foggy image,tarel’s Results,He’Results, and our Results

These indicators e,r,h and s are evaluvated for the comparison experiments on four images.Fig2,Fig3,Fig4,Fig5

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Table 1:Comparison of the e values

E	Tarel	He	Our
Fig.3.10(a)	0.17654	0.15058	0.19606
Fig.3.10(b)	0.29995	0.33129	0.57548
Fig.3.10(c)	0.98097	1.21450	1.43480
Fig.3.10(d)	0.56917	0.27237	0.84829

Table 2: Comparison of the r values

R	Tarel	He	Our
Fig.3.10(a)	1.4285	1.1466	3.4980
Fig.3.10(b)	1.5580	1.8001	4.5407
Fig.3.10(c)	1.5903	2.3680	7.1053
Fig.3.10(d)	1.9691	1.33084	2.6720

Table 3: Comparison of the h values

h(%)	Tarel	He	Our
Fig.3.10(a)	55.0869	61.3138	64.2913
Fig.3.10(b)	61.5267	68.3160	73.5635
Fig.3.10(c)	37.5762	54.4047	69.7086
Fig.3.10(d)	50.5728	50.4467	55.7496

Table 4: Comparison of the s values

S	Tarel	He	Our
Fig.3.10(a)	1.3517	1.0480	3.0851
Fig.3.10(b)	1.5978	1.6269	3.8166
Fig.3.10(c)	1.8889	2.1009	6.2045
Fig.3.10(d)	2.2030	1.3483	2.9110

As can be observed from above tables, our method is able to achieve fog removal while restoring more visible edges.Third table that the histogram results of restored images obtained by our method are very close to the histogram results of the orginal images, hich means our method can accurately retains the colour of te objects. From table four we ca deduce that our method can preserveedge characterstics effectively. In conclusion, our method clearly outperforms othe methods.

V. CONCLUSION

In this paper, propose a novel defogging method based on local extrema, which relies only on the assumption that the depth map tends to be smooth everywhere except at edges. Inspired by techniques in empirical data analysis and morphological image analysis, use the method based local extrema to estimate atmospheric veil. After obtaining multi scale restoration results,[11] then we improve the visual effects through multi-scale tone manipulation algorithm, which is very effective for controlling the amount of local contrast at different scales. Compared with other defogging methods,[1-7] the experiment results demonstrate method can achieve more ideal defogging results without requiring any additional information (e.g., depth information) or any user interactions. This method can be efficient for practical application in real fog fields. On the other hand, our work shares the common limitation of most image defogging methods, that is, does not always obtain equally good results on heavy haze scenes. Our work may result in poor effect when failing to identify the local minima and local maxima accurately. Therefore, the parameter settings under different weather conditions are very important.

In future work, are going to investigate more optimal schemes for determining the parameters of multi-scale tone manipulation algorithm and the calculation of extremal envelope in order to further improve the visual effects and the operational efficiency.

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