Review Paper on Haze Removal Techniques

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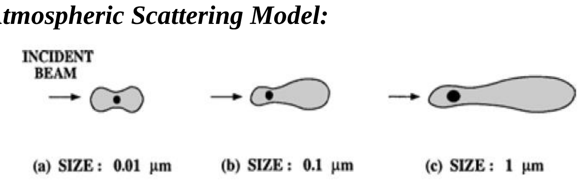
Abstract— Haze is a one of the atmospheric effect on image. It is formed because of airlight and attenuation process. There are different haze removal technique have been proposed. The dark channel prior based haze removal has provided quite promising results over the available techniques. Many researchers have also proposed various improvements in the dark channel prior to get better results. Paper as compare various priors and discussed efficiency of a novel color attenuation prior described. The overall objectives of this review are to evaluate methods for haze removal and compare color attenuation prior with DCP and other popular methods for efficiency.

Keywords: Airlight, haze, DCP, etc

I. INTRODUCTION

Outdoor images which are taken in bad weather (e.g., foggy or hazy) usually lose contrast and fidelity, that results from the fact that light is absorbed and scattered by the turbid medium such as particles and water droplets in the atmosphere during the process of propagation. Moreover, most automatic systems, which strongly depend on the definition of the input images, fail to work normally caused by the degraded images. Therefore, improving the technique of image haze removal will benefit many image understanding and computer vision applications such as aerial imagery, image classification, image/video retrieval, remote sensing and video analysis and recognition. Since concentration of the haze is different from place to place and it is hard to detect in a hazy image, image dehazing is a challenging task.

Atmospheric Scattering Model:



A particle scatters incident light. The nature of scattering depends on material properties, shape and size. The exact form and intensity of the scattering pattern varies dramatically with particle size.

Haze and fog are an atmospheric effect, but they are different, fog is thick and opaque effect while haze is thin and translucent effect.

1. ***Haze:***It is constituted of *aerosol* (small particles suspended in gas). Main sources are volcanic ashes, foliage exudation, combustion products, sea salt. Haze particles are larger than air molecules but smaller than fog droplets produce a distinctive gray or bluish hue and affects visibility extends to altitudes of several Km.
2. ***Fog:***It has same origins as haze, associated with an increase in relative humidity of an air. Size of water droplets increases with humidity. Haze can turn into fog (transition state: ***mist***). It reduces visibility more than haze which extends to altitudes of few hundred meters.

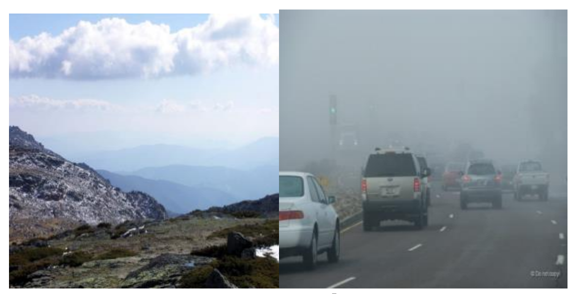


Fig 1: Haze and Fog

Mathematical Model:

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

$$t(x) = e^{-\beta d(x)} \qquad (2)$$

I(**x**) is the observed radiance at **x. J**(**x**) is the original scene radiance at **x. A** is the ***airlight.*** t(**x**), scalar called ***transmission****:* describes how the radiance of a point in the scene is attenuated according to its distance *d* from the observer. **I, J, A** are (R, G, B) triplets. In order to remove the effect of haze, one must recover J(x) Quantities **A** and *t* are typically unknown **I**(**x**) is known

II. LITERATURE REVIEW

Methods presented in earlier studies had required multiple images to perform dehazing. Author [3-5] is prepare technique Histogram based used Histogram of image consisting number of pixels with particular brightness values is used to estimate depth, has limitation Dehazing effect is limited. Using multiple image technique, to improve dehazing performance, multiple images were used, has limitation in online image dehazing applications and may need a special imaging sensor. There are three categories of such works published as shown below:

1. ***Polarization based method:***Authors [6-8] have used the polarization property of scattered light to restore the scene depth information from two or more images taken with different degrees of polarization, has limitation. This method cannot be applied to dynamic scenes for which the changes are more rapid than the filter rotation. This method may fail in very dense haze.
2. ***Weather condition based method:***Authors[9-11] have used Multiple images of the same scene are captured under different weather conditions to be used as reference images with clear weather conditions, has

limitation These images possess different characteristics of the contributing medium and also enhance the visibility. This method unable to handle the dynamic scene and cannot give the better result suddenly.

3. ***Depth map information based method:*** In this method authors [12,13] have used the 3D geometrical model and texture of the scene. This 3D model aligns hazy image and provides scene depth and accurate results, has limitation this method is not automatic.

Single image dehazing methods:

This method uses the single input image and this method depends upon statistical assumption and essence of the scene. In image processing problems some priors can be used to pose a problem in well manor. Priors help to prepare a problem for finding the solution in efficient way. Ill posed problem can be converted in well posed problem using prior. Single image haze removal has been a challenging problem due to its ill-posed nature. Various priors are used in computer vision e.g. smoothness prior, sparseness prior, exemplar-based prior, Dark Channel Prior (DCP)

Recently, significant progress has been made in single image dehazing based on the physical model. Under the assumption that the local contrast of the haze-free image is much higher than that in the hazy image, various haze removal methods have been proposed.

Table 1: Single image haze removal techniques

Technique	**Description**	**Remarks**
Markov Random Field (MRF). -Tan [14]	It is a method that takes into account the characteristic that a haze-free image has a higher contrast than a hazy image. By maximizing the local contrast of the input hazy image, it enhances the visibility but introduces blocking artefacts around depth discontinuities.	Tan's approach is able to achieve impressive results; it tends to produce over-saturated images.
Independent Component Analysis (ICA),	It is a method that infers the medium transmission by estimating the radiance of the scene. The underlying assumption is that the transmission and surface shading are locally uncorrected, which does not hold under a dense haze.	the approach is time-consuming and cannot be used for grayscale image dehazing
dark-object subtraction (DOS) [16]	This is a technique which allows the user to select a relativeatmospheric scattering model to predict the haze values for all the spectral bands from a selected starting band haze value. This method normalizes the predicted haze values for the different gain and offset parameters used by the imaging system	The method needs to establish a better relationship between the starting haze value and the type of atmospheric conditions present during data collection.
Dark channel prior (DCP) He *et al.* [17]	Observing the property of haze-free outdoor images, He et al. proposed a novel prior—dark channel prior (DCP).The DCP is based on the property of "dark pixels," which have a very low intensity in at least one color channel, except for the sky region. Owing to its effectiveness in dehazing, the majority of recent dehazing techniques have adopted the DCP.	The DCP approach is simple and effective in most cases. However, it cannot well handle the sky images and is computational ly intensive

Dark Channel Prior Technique:

This method by He *et al.* [17] estimates transmission map and air-light to recover original image from foggy image. To estimates the transmission map, it uses the lowest intensity pixel of image in three colour planes in patch sizes of different values. Block diagram for DCP algorithm is shown in Figure 2.

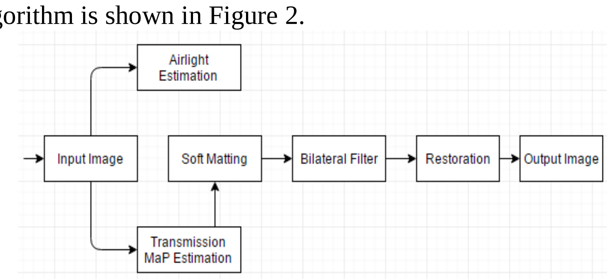


Fig 2: DCP-based dehazing algorithm

Fig 2 shows the original DCP-based dehazing algorithm in He *et al.* [17]. The follow-up methods are based on the basic structure presented in [17] but differ in each step of the dehazing procedure. Table 3 shows the DCP-based dehazing algorithms from [18-24, 26-32] that are investigated in this paper. DCP is very popular prior but the time-consuming soft matting was not much efficient.

Various improvements in DCP are proposed as discussed below:

Table 2: Improvements in DCP

Step	**Replaced with**	**Performance**
Soft matting	Standard median filtering [19]	Improved efficiency
	Median of median filtering [20]	Improved efficiency
	Guided joint bilateral filtering [25]	Improved efficiency
	Guided image filtering [26,27]	Improved efficiency
Image modelling	Factorial MRF [29, 30]	Accurate estimation of scene radiance
Restoration	Effective regularization dehazing by exploring inherent boundary constraint [31]	Improved dehazing quality

Despite the remarkable progress, the limitation of the state-of-the-art methods lies in the fact that the haze-relevant priors or heuristic cues used are not effective or efficient enough.

III. COLOR ATTENUATION PRIOR

In [1], Authors propose a novel color attenuation prior for single image dehazing. This simple and powerful prior can help to create a linear model for the scene depth of the hazy image. By learning the parameters of the linear model with a supervised learning method, the bridge between the hazy image and its corresponding depth map is built effectively. With the recovered depth information, we can easily remove the haze from a single hazy image. An overview of the proposed dehazing method is shown in Figure 3. The efficiency of this dehazing method is dramatically high and the dehazing effectiveness is also superior to that of prevailing dehazing algorithms.

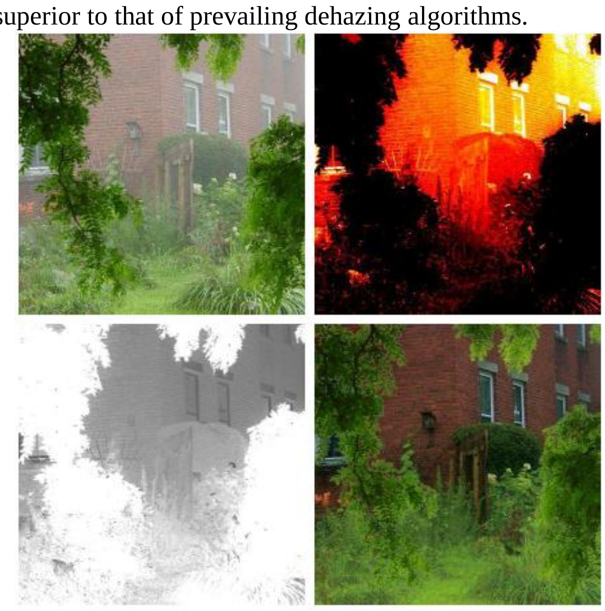


Fig 3: An overview of the proposed dehazing method. Top-left: Input hazy image. Top-right: Restored depth map. Bottom-left: Restored transmission map. Bottom-right: Dehazed image.

To detect or remove the haze from a single image is a challenging task in computer vision, because little information about the scene structure is available. In spite of this, the human brain can quickly identify the hazy area from the natural scenery without any additional information. This inspired us to conduct a large number of experiments on various hazy images to find the statistics and seek a new prior for single image dehazings. Interestingly, authors in [1] find that the brightness and the saturation of pixels in a hazy image vary sharply along with the change of the haze concentration.

Since the concentration of the haze increases along with the change of the scene depth in general, they have made an assumption that the depth of the scene is positively correlated with the concentration of the haze.

As the difference between the brightness and the saturation can approximately represent the concentration of the haze, a linear model has been created, i.e., a more accurate expression, as follows:

$$d(x) = \boldsymbol{\theta_0} + \boldsymbol{\theta_1} v(x) + \boldsymbol{\theta_2} s(x) + \varepsilon(x), \quad (4)$$

Where x is the position within the image, d is the scene depth, v is the brightness component of the hazy image s is the saturation component, θ_0, θ_1, θ_2 are the unknown linear coefficients, $\varepsilon(x)$ is a random variable representing the random error of the model, and ε can be regarded as a random image. By using supervised learning method, the prepared method used 500 training samples containing 120 million scene points to train the linear model. There are 517 epochs in case, and the best learning result is that θ_0= .121779, $\theta 1$= 0.959710, θ_2= −0.780245, σ = 0.041337. Once the values of the coefficients have been determined, these can be used for any single hazy image. These parameters will be used for restoring the scene depths of the hazy images in [1]. After calculating depth vector the algorithm has determined values of A and J(x) to recover the image according to atmospheric scattering model.

Effectiveness of color attenuation prior:

In [1], authors have proposed novel linear color attenuation prior, based on the difference between the brightness and the saturation of the pixels within the hazy image. By creating a linear model for the scene depth of the hazy image with this simple but powerful prior and learning the parameters of the model using a supervised learning method, the depth information can be well recovered. By means of the depth map obtained by the proposed method, the scene radiance of the hazy image can be recovered easily. Experimental results show that the proposed approach achieves dramatically high efficiency and outstanding dehazing effects as well.

IV. CONCLUSION

The proposed method is have categorized and compared with various haze removal techniques. For the purpose of single image haze removal, DCP was considered very effective prior but color attenuation is simple and effective prior. It can give faster results with better dehazing effects.

REFERENCES

[1] Qingsong Zhu, et al. “A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior”, IEEE Trans. On Image Processing, Vol. 24, No. 11, November 2015.

[2] Sungmin Lee, et al. “A review on dark channel prior based image dehazing algorithms” EURASIP Journal on Image and Video Processing, 2016.

[3] T. K. Kim, J. K. Paik, and B. S. Kang, “Contrast enhancement system using spatially adaptive histogram equalization with temporal filtering,” IEEE Trans. Consume. Electron. vol. 44, no. 1, pp. 82–87,Feb. 1998.

[4] J. A. Stark, “Adaptive image contrast enhancement using generalizations of histogram equalization,” IEEE Trans. Image Process., vol. 9, no. 5, pp. 889–896, May 2000.

[5] J.-Y. Kim, L.-S. Kim, and S.-H. Hwang, “An advanced contrast enhancement using partially overlapped sub-block histogram equalization,” IEEE Trans. Circuits Syst. Video Technol., vol. 11, no. 4, pp. 475–484,Apr. 2001.

[6] Y. Y. Schechner, S. G. Narasimhan, and S. K. Nayar, "Instant dehazing of images using polarization," in Proc. IEEE Conf. Comput. Vis. Pattern Recognit. (CVPR), 2001, pp. I-325–I-332.

[7] S. Shwartz, E. Namer, and Y. Y. Schechner, "Blind haze separation," in Proc. IEEE Conf. Comput. Vis. Pattern Recognit. (CVPR), vol. 2. 2006, pp. 1984–1991.

[8] Y. Y. Schechner, S. G. Narasimhan, and S. K. Nayar, "Polarization-based vision through haze," Appl. Opt., vol. 42, no. 3, pp. 511–525, 2003.

[9] S. G. Narasimhan and S. K. Nayar, "Chromatic framework for vision in bad weather," in Proc. IEEE Conf. Comput. Vis. Pattern Recognit. (CVPR), Jun. 2000, pp. 598–605.

[10] S. K. Nayar and S. G. Narasimhan, "Vision in bad weather," in Proc. IEEE Int. Conf. Comput. Vis. (ICCV), vol. 2. Sep. 1999, pp. 820–827.

[11] S. G. Narasimhan and S. K. Nayar, "Contrast restoration of weather degraded images," IEEE Trans. Pattern Anal. Mach. Intell., vol. 25, no. 6, pp. 713–724, Jun. 2003.

[12] S. G. Narasimhan and S. K. Nayar, "Interactive (de) weathering of an image using physical models," in Proc. IEEE Workshop Color Photometric Methods Compute. Vis., vol. 6. France, 2003, p. 1.

[13] J. Kopf et al., "Deep photo: Model-based photograph enhancement and viewing," ACM Trans. Graph., vol. 27, no. 5, p. 116, Dec. 2008.

[14] R. T. Tan, "Visibility in bad weather from a single image," in Proc. IEEE Conf. Compute. Vis. Pattern Recognition. (CVPR), Jun. 2008, pp. 1–8.

[15] R. Fattal, "Single image dehazing," ACM Trans. Graph., vol. 27, no. 3,p. 72, Aug. 2008.

[16] P. S. Chavez, Jr., "An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data," Remote Sens. Environ., vol. 24, no. 3, pp. 459–479, Apr. 1988.

[17] K. He, J. Sun, and X. Tang, "Single image haze removal using dark channel prior," IEEE Trans. Pattern Anal. Mach. Intell., vol. 33, no. 12, pp. 2341–2353, Dec. 2011.

[18] S.-C. Pei and T.-Y. Lee, "Nighttime haze removal using color transfer pre-processing and dark channel prior," in Proc. 19th IEEE Conf. Image Process. (ICIP), Sep. /Oct. 2012, pp. 957–960.

[19] K. B. Gibson, D. T. Vo, and T. Q. Nguyen, "An investigation of dehazing effects on image and video coding," IEEE Trans. Image Process., vol. 12,no. 2, pp. 662–673, Feb. 2012.

[20] J. Yu, C. Xiao, and D. Li, "Physics-based fast single image fog removal," in Proc. IEEE 10th Int. Conf. Signal Process. (ICSP), Oct. 2010, pp. 1048–1052.

[21] B. Xian, F. Guo, and Z. Cai, "Improved single image dehazing using dark channel prior and multi-scale retinex," in Proc. Int. Conf. Intell. Syst. Design Eng. Appl., Oct. 2010, pp. 848–851.

[22] Q. Zhu, S. Yang, P. A. Heng, and X. Li, "An adaptive and effective single image dehazing algorithm based on dark channel prior," in Proc. IEEE Conf. Robot. Biomimetics (ROBIO), Dec. 2013, pp. 1796–1800.

[23] C. Xiao and J. Gan, "Fast image dehazing using guided joint bilateral filter," *Vis. Comput.*, vol. 28, nos. 6–8, pp. 713–721, Jun. 2012.

[24] Y. Xiang, R. R. Sahay, and M. S. Kankanhalli, "Hazy image enhancement based on the full-saturation assumption," in *Proc. IEEE Conf.Multimedia Expo Workshops (ICMEW)*, Jul. 2013, pp. 1–4.

[25] K. He, J. Sun, and X. Tang, "Guided image filtering," IEEE Trans. Pattern Anal. Mach. Intell., vol. 35, no. 6, pp. 1397–1409, Jun. 2013.

[26] A. Levin, D. Lischinski, and Y. Weiss, "A closed-form solution to natural image matting," IEEE Trans. Pattern Anal. Mach. Intell., vol. 30, no. 2, pp. 228–242, Feb. 2008.

[27] J.-P. Tarel and N. Hautiere, "Fast visibility restoration from a single color or gray level image," in Proc. IEEE 12th Int. Conf. Comput. Vis. (ICCV), Sep. /Oct. 2009, pp. 2201–2208.

[28] J.-P. Tarel, N. Hautière, L. Caraffa, A. Cord, H. Halmaoui, and D. Gruyer, "Vision enhancement in homogeneous and heterogeneousfog," IEEE Intell. Transp. Syst. Mag., vol. 4, no. 2, pp. 6–20, Apr. 2012.

[29] L. Kratz and K. Nishino, "Factorizing scene albedo and depth from a single foggy image," in Proc. IEEE 12th Int. Conf. Comput. Vis. (ICCV), Sep. /Oct. 2009, pp. 1701–1708.

[30] K. Nishino, L. Kratz, and S. Lombardi, "Bayesian defogging," Int. J. Comput. Vis., vol. 98, no. 3, pp. 263–278, Jul. 2012.

[31] G. F. Meng, Y. Wang, J. Duan, S. Xiang, and C. Pan, "Efficient image dehazing with boundary constraint and contextual regularization," in Proc. IEEE Int. Conf. Comput. Vis. (ICCV), Dec. 2013, pp. 617–624.

[32] K. Tang, J. Yang, and J. Wang, "Investigating haze-relevant features in a learning framework for image dehazing," in Proc. IEEE Conf. Co