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PERFORMANCE EVALUATION OF UNIVERSAL DEHAZING WITH DIRECTED FILTER METHOD

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ABSTRACT

Abstract Haze is an atmospheric individuality that significantly degrades the visibility of outdoor scenes. This is mainly due to the atmosphere particles that absorb and scatter the light. We build the spread map by estimating the atmospheric light except a continuous region which has no edge information. The method performs a per-pixel manipulation, which is straight forward to implement and then apply the Directed filter to improve the image quality. The experimental results demonstrate that the method yields results comparative to and even better than the more complex state-of-the-art techniques, having the advantage of being appropriate for real-time applications.

INDEX TERMS: Haze detection, Dehazing, Directed filter, universal dehazing and single image dehazing.

1. INTRODUCTION

Haze is an irritating factor when it shows up in the image since it causes poor visibility. This is the major problem of some applications in the field of computer vision, such as surveillance, object recognition, etc. In order to obtain the clear images, haze removal is inevitable. Fog, mist and some other particles that disgrace the scene image are the results of atmospheric combination and light scattering. The radiance achieved to camera along the sightline is decreased due to atmospheric light and it is replaced by previously scattered light, which is called the airlight. This degradation will cause the image to lose contrast and color correctness. Furthermore, the airlight which affect the image depends on the depth of the scene. This knowledge is commonly used for dehazing problems. We also adopt this clue to solve the haze removal problem. Image haze removal has gotten a growing interest recently. More and more methods are introduced in the past three years. Nevertheless, dehazing is a challenging topic since the haze is dependent on the unknown depth information. Often, the images of open-air scenes are degraded by bad weather conditions. In such cases, atmospheric phenomena like haze and fog degrade significantly the visibility of the captured scene. Since the aerosol is misted by additional particles, the reflected light is scattered and as a result, distant objects and parts of the scene are less visible, which is characterized by reduced contrast and faded colors. Restoration of images taken in these specific conditions has caught increasing attention in the last years. This task is important in several outdoor applications such as remote sensing, intelligent vehicles, object recognition and surveillance. In remote sensing systems, the recorded bands of reflected light are processed [1], [2] in order to restore the outputs. Multi-image techniques [3] solve the image dehazing problem by processing several input images that have been taken in different atmospheric conditions. Another alternative [4] is to assume that an approximated 3D geometrical model of the scene is given. In this paper of Treibitz and Schechner [5] different angles of polarized filters are used to estimate the haze effects. A more challenging problem is when only a single degraded image is accessible. Solutions for such cases have been introduced only recently [6]–[9]. In this paper we introduce an alternative single-image based strategy that is able to accurately dehaze images using only the original degraded information. An extended abstract of the core idea has been recently introduced by the authors in [10]. Our technique has some similarities with the previous approaches of Tan [7] and Tarel and Hautière[9], which enhance the visibility in such outdoor images by manipulating their contrast. However, in contrast to existing techniques, we built our approach on universal dehazing with directed filter. We are the first to demonstrate the utility and effectiveness of a fusion-based technique for dehazing on a single degraded image then we made the universal image dehazing model with directed filter. In this work, our goal is to develop a simple therefore; all the universal dehaze processing steps are designed in order to support these important features. The main concept behind universal dehaze based technique is that two input images from the original input with the aim of recovering the visibility for each region of the scene in at least one of them. Additionally, the universal dehaze image enhancement technique estimates for each pixel the desirable perceptual based qualities (called weight maps) that control the contribution of each input to the final result. In order to derive the images that fulfill the visibility assumptions (good visibility for each region in at least one of the inputs) required for the fusion process, we analyze the optimal model for this type of degradation.

2. HAZE DETECTION BY UNIVERSAL DEHAZING METHOD

Human eyes are more susceptible to brightness than color. Therefore we use the atmospheric light estimation and produce a transmission map in the YC_bC_r color channels. The atmospheric light is estimated from the most dense pixel. The existing algorithm picks up the top 0.1% brightest pixels in the dark channel prior. Sine an image does not have information on the edge of the sky or a wall in the area, the mis-estimated value of the atmospheric light results in failure of the defogging (dehazing) algorithm. Therefore we use the edge information to represent the neighboring pixel's relative depth information. With this relative depth information we can construct the corresponding atmospheric light to restrain the edge halation. We produce the transmission map by estimating the atmospheric light except a continuous region which has no edge information. And the transmission map is given as,

$$\tilde{t}(x) = 1 - \min_c\left(\min_{y \in \Omega(x)}\left(\frac{I^c(y)}{A}\right)\right), \quad (4)$$

$$J(x) = \frac{I(x) - A}{\max(\tilde{t}(x), t_0)} + A, \quad (5)$$

Where 0 t restricts the transmission t (x) to a lower bound 0 t ,which means that a small amount of fog are preserved in very dense fog regions. In the experiment we used 0 t _ 0.1 .Color distortion problem may occur in the compensation process. To solve this problem, the image restored by color correction using statistical RGB channel feature extraction of image. We calculate the RGB channel ratio between foggy and defogged images for color correction with weighted image. The RGB channel ratio is defined as,

$$R\_Ratio = mean(R\_r) / mean(O\_r)$$
$$G\_Ratio = mean(R\_g) / mean(O\_g),$$
$$B\_Ratio = mean(R\_b) / mena(O\_b)$$

Where R represents the defogged image an O the foggy image. As a result, we can obtain the color-corrected image using color matching of RGB channels of restored image, such as

$$J = \begin{pmatrix} R\_r_1 & R\_g_1 & R\_b_1 \\ R\_r_2 & R\_g_2 & R\_b_2 \\ & \cdots & \\ R\_r_k & R\_g_k & R\_b_k \end{pmatrix} \times \begin{pmatrix} R\_Ratio & 0 & 0 \\ 0 & G\_Ratio & 0 \\ 0 & 0 & B\_Ratio \end{pmatrix}$$

Where J represents the color-corrected image, and k the number of pixels.

3. DIRECTED FILTER IMAGE MODELLING FOR HAZE EXTRACTION

The observed brightness of a capture image in the presence of haze can be modelled based on the atmospheric optics [6, 7,11] via

$$I(x) = J(x)t(x) + A(1 - t(x)) \qquad (6)$$

Where, I(x) is the observed haze image, J(x) is scene irradiance(the clear haze-free image), A is the airlight that represents the ambient light in the atmosphere. t(x)ϵ[0, 1] is the transmission of the light reflected by the object, which indicates the depth information of the scene objects directly. J(x)t(x)on the right hand side is called direct attenuation, which describes the scene radiance and its decay in the medium. The second term A(1-t(x))is the atmospheric veil (atmospheric scattering light), which causes fuzzy, color shift, and distortion in the scene. The goal of haze removal is to recover J(x), A and t (x) from I(x).

4. IMAGE DEHAZING

In this section, we will describe in detail. The rough down-sampled transmission and the air-light are estimated firstly, then the transmission is smoothed and up sampled using a directed filter, and finally the haze-free image is restored.

4.1 EXTRACT THE TRANSMISSION

The core of haze removal for an image is to estimate the airlight and transmission map. Assuming the airlight is already known, to recover the haze

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free image, the transmission map should be extracted first. He et al. [8] found that the minimum intensity in the non-sky patches on haze free open-air images should have a very low value, which is called dark channel prior. Formally, for an image J, the dark channel value of a pixel x is defined as:

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

Where, J^c is a color channel of J ; Ω(x) is a patch around x. By assuming the transmission in a local patch is constant and taking the min operation to both the patch and three color channels, the haze imaging model in (4) can be transformed as:

$$\min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) = \tilde{t}(x)\min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)}(\frac{J^c(y)}{A^c}))+(1-\tilde{t}(x)) \quad (7)$$

where, $\tilde{t}(x)$ is the patch transmission. Since A is always positive and the dark channel value of a haze-free image J tends to be zero according to the dark channel prior, we have

$$\min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)}(\frac{J^c(y)}{A^c})) \to 0$$

Then the transmission can be exacted simply by:

$$\tilde{t}(x) = \min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \quad (8)$$

Although the dark channel prior is not a good prior for the sky regions, fortunately, both sky regions and non-sky regions can be well handled by (8) since the sky is infinitely distant and its transmission is indeed close to zero. In practice, the atmosphere is not absolutely free of any particle even in clear weather. Therefore, a constant parameter ω(0<ω≤1) is introduced into(8) to keep a small amount of haze for the distant objects:

$$\tilde{t}(x) = 1- \omega \min_{c\in\{r,g,b\}}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \quad (9)$$

The estimated transmission maps using (9) is practical. The main problems are some halos and block artifacts. This is because the transmission is not always constant in a patch. Several techniques were proposed to refine the transmission map, such as soft matting and directed joint bilateral filter. These techniques were functional on the transmission maps of the original foggy images and usually several operations should be used to achieve a good result, which could be computational intensive. For image haze removal, the time complexity is a critical difficulty that

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needs to be addressed. High time complexity of dehazing may make the algorithm impracticable.

4.2 REFINE THE TRANSMISSION

To improve the efficiency, in the present execution, the transmission map is obtained form a down-sampled minimum channel image. Then, it is refined and up-sampled by using directed filter, which can be explicitly expressed by [11]:

$$t_i = \sum_j W_{ij}(J^g)\varepsilon_j \quad (10)$$

$$W_{ij}(J^g) = \frac{1}{|w|^2}\sum_{k:(i,j)\in w_k}\left(1+\frac{(J_i^g-\mu_k)(J_j^g-\mu_k)}{\sigma_k^2+\varepsilon}\right) \quad (11)$$

Where, J_g is the guidance image; μ_k and σ_k^2 are the mean and variance of J_g in w_k ; |w| is the number of pixels in w_k. ε is a regularization parameter. The refined operation on a down-sampled minimum channel image leads to a low time complexity and helps to reduce halos and block artifacts. Joint up sampling using directed filter is applied to obtain the full transmission map. The directed filter is reported to be a fast and non-approximate linear-time algorithm, which can perform as an edge preserving, smoothing operator like the bilateral filter, but does not suffer from the gradient reversal artifacts. Moreover, the directed filter has an O(N) time (in the number of pixels N)exact algorithm for both gray-scale and color images.

4.3 PERFORMANCE PARAMETERS

For a good algorithm, values of these evaluation metrics should be high.

Modelling the Markov pdf parametrically involves the data driven optimal estimation of the parameters associated with the potential functions Vc. The model parameters must be estimated for each data set as part of the image processing algorithm. In our algorithms, the noise variance σ2 in (10) and the parameter a in the coefficient MRF pdf in (11) are unknown. Thus, we need to estimate these parameters in our algorithms. Because we assume that the noise in the fusion model is a Gaussian noise, it is straightforward to estimate the noise variance by the maximum likelihood (ML) criterion. It is given by

$$\sigma^2 = \frac{1}{MN}\sum_i (Y_i - H_i X)^T (Y_i - H_i X) \quad (13)$$

The direct ML estimation of the parameters associated with the pdf of H is known to be a difficult problem [32]. The ML estimate of a is

$$\hat{a} = \arg\min_a V_c(H, a) - \ln Z_H$$

(14)

The potential function $V_c(H, a)$ can be simply computed. However, the normalization term ZH involves a summation over all possible configurations of H, which is practically impossible due to the large computation time. Note that, for two source images with size 300 *300, H has a total of 490000 possible configurations. An alternative method for approximation to ML estimation is maximum pseudo likelihood (MPL) estimation, which was proposed by Besag[15]. The MPL estimation method is a suboptimal method, which is given by

$$\hat{a} = \arg\min_a \Sigma_s V_c(H(s), a) - \ln Z_{H(s)}.$$

(15)

The differences among the fused results are usually difficult to be measured only based on observation, particularly when the fused images are multiband. Objective and quantitative analysis can benefit to a comprehensive evaluation. Various image quality indices have been developed for the purpose of image fusion [12]–[13]. Some of these indices validate the spatial resolution, while others focus on the spectral properties of the obtained fused result. In this paper, we employ three such indices.

4.3.1 SNR

The SNR in decibels, as shown in (19), is a direct index to compare the fused image to the reference one [16].For multiband images, it can be calculated band-by-band and also globally averaged SNR

$$SNR(Z, \hat{Z}) = 10\log_{10}\frac{\sum Z^2}{\sum(Z-\hat{Z})^2},$$

(16)

4.3.2 Universal Image Quality Index (UIQI)

A UIQI [14] has been widely used for image similarity evaluation and was also applied to validate fusion techniques [13]. UIQI of two images (A and B) is defined as

$$Q = \frac{4\sigma_{AB}\mu_A\mu_B}{(\sigma_A^2+\sigma_B^2)(\mu_A^2+\mu_B^2)} \quad (17)$$

This quality index models any distortion as a combination of three different factors: loss of correlation, luminance distortion, and contrast distortion. The dynamic range of Q is [−1,1], and the best value 1 is obtained if A = B. When applying this index to a multiband image, it is applied band-by-band and averaged over all bands. [16].

4.3.3 Performance of the image compression coding

It is necessary to define a measurement that can estimate the difference between the original image and the decoded image. Two common used measurements are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR), which are defined in (2.3) and (2.4), respectively. f(x,y) is the pixel value of the original image, and f'(x,y)is the pixel value of the decoded image. Most image compression systems are designed to minimize the MSE and maximize the PSNR.

$$MSE = \sqrt{\frac{\sum_{x=0}^{W-1}\sum_{y=0}^{H-1}[f(x,y)-f'(x,y)]^2}{WH}} \quad (18)$$

$$PSNR = 20\log_{10}\frac{255}{MSE} \quad (19)$$

5. RESULT ANALYSIS

The algorithm proposed here will remove haze from an image surface without former knowledge of the haze location upon that surface. The proposed method is based on determining the illumination profile of the image surface. This profile is then used to remove the haze. It is implemented using MATLAB 7.9.0 (R2009b) on i-5 processor with 4-GB RAM. The simulations have been tested on aerial images in figure 2; Figure 2showsthe Original Image of forest and haze Removed Image.

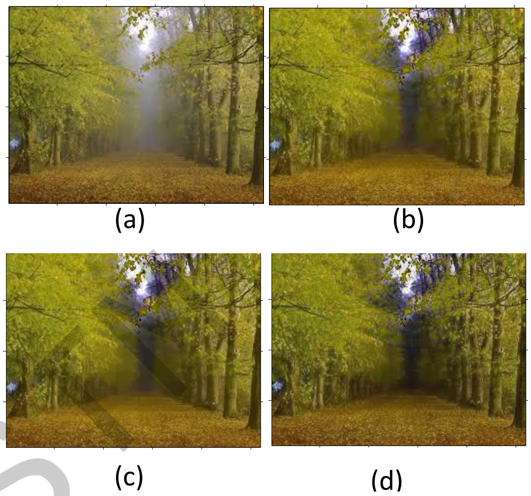

Figure: 3 (a) Original Image of forest, (b) Dehazed Image by using Multi scale Fusion (c) Dehazed Image by using Universal Dehazing (d) Dehazed Image After Directed filter.

Table 1 Comparison parameters for forest image

Method	Variance	Mean	SNR	UIQI
Multiscale Fusion	0.1237	0.4923	6.6155	4.8557
Universal Dehazing	0.0807	0.3263	8.1238	6.4175

6. CONCLUSION AND FUTURE SCOPE

In this paper, a fast and effective method for real-time image and video dehazing is proposed. In the presented algorithm, the airlight and the down-sampled transmission can be estimated and extracted easily. Then using a directed filter, the transmission can be further refined and up-sampled. Results demonstrate the presented method abilities to remove the haze layer and achieve real-time performances. It is believed that many applications, such as outdoor surveillance systems, intelligent vehicle systems, etc, could benefit from the proposed method.

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