AN IMPROVED SINGLE IMAGE DEHAZING ALGORITHM BASED ON DOWNSAMPLING

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Abstract: Now-a-days our environment is full of pollution. Pollution includes particles, water droplets, fog, smoke due to atmospheric absorption and scattering. Due to this the outdoor images suffer degradation, which is termed as Haze. The removal of this Haze is called Dehazing. In this paper, we propose a fast haze removal method, which is an improved version of an existing method using dark channel prior method proposed by He et al. [1]. In this method, we reduced the computational time by improving the method to estimate dark channel. Our proposed method uses a downsampled image and do not need a soft – matting process [2]. Experiments have proved that our proposed method is faster than existing He's dark channel method with acceptable image quality.

Keywords - **Dehaze, Haze removal, dark channel, down sampling.**

I. INTRODUCTION

In recent years, Everything has became automated like self-driving techniques and underwater working robots. For these applications fast and advanced image recognition techniques are required. Due to Haze outdoor or underwater images undergo degradation. Therefore, Image quality enhancement techniques on haze removal has became popular. He et al [1] proposed a method using dark channel prior. He's method is based on a statistical prior knowledge that most local patches in clear images contain some pixels which have very low intensities in at least one color channel, which is called dark channel [1]. The haze can be removed effectively by using dark channel prior. However, the main drawback in He's method is processing speed. A number if methods have been proposed to increase the processing speed [3,4]. In this method we proposed a fast haze removal method , which is an improved version of He's method [1]. In this method, Computational time is significantly reduced by improving dark channel estimation, which uses a down-sampled image and do not need a soft-matting process [2]. Experiments have proved that our proposed method is faster than existing He's dark channel method with acceptable image quality.

II. RELATED WORK (DARK CHANNEL PRIOR [1])

A hazy image can be represented by a combination of direct light from an object, ambient light and haze. This image can be expressed as Eq. (1) [1]:

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

Where **I** is an observed image including haze, **J** is direct light from an object, **A** is ambient light and the ratio is determined by the value of the medium transmission t. **x** is the coordinates of the image.

2.1 Medium transmission estimation $t(x)$

T is the transmission medium, Which is expressed by the following equation [1]:

$$t(\boldsymbol{x}) = e^{-\beta d(x)} \, , \tag{2}$$

Where β is the scattering coefficient of the atmosphere, and d is depth.
The property that at least one of the RGB components takes a low intensity in the clear image is used in He's method [1]. For the minimum value of patch (15 × 15), Eq. (1) is modified as Eq. (3) [1]:

$$\min_{y\in\Omega(x)}\left(\min_{c\in\{R,G,B\}}\frac{I^c(y)}{A^c}\right) = t'(\boldsymbol{x})\min_{y\in\Omega(x)}\left(\min_{c\in\{R,G,B\}}\frac{I^c(y)}{A^c}\right) + \big(1 - t'(\boldsymbol{x})\big), \tag{3}$$

Where $\Omega(\boldsymbol{x})$ is a local patch centered at **x**, t' is the transmission medium based on local patch. Under the condition of dark channel prior, the first term of right hand side in eq. (3) tend to zero. Then, the transmission medium t' can be estimated by eq. (4) [1]:

$$t'(\boldsymbol{x}) = 1 - \omega \min_{y\in\Omega(x)}\left(\min_{c\in\{R,G,B\}}\frac{I^c(y)}{A^c}\right), \tag{4}$$

Where ω is the haze removal rate (in He's method it is 0.95) and is considered to the Human perception for depth scene [1]. As $t'(\boldsymbol{x})$ is calculated by each local patch, $t'(\boldsymbol{x})$ is not smooth in edge region. So, soft-matting [2] is used to obtain a smooth image.

2.2 Ambient light estimation A

The ambient light is the RGB component of the pixel having the highest luminance value in the input image ***I***. Mostly the color of the white object in the image is considered as ambient light. Hence, the optimum ambient light is calculated using the dark channel value. Ambient light is the portion with the highest haze in the input haze image. In He's method, initially they pick the top 0.1% brightest pixels in the dark channel image, from those pixels they choose high intensity pixels in the input image **I** [1].

2.3 Direct light estimation J (Haze removal)

From the estimated $t'(\boldsymbol{x})$ and **A** we calculate the Haze removal. Eq. (1) is converted as Eq. (5) [1];

$$\boldsymbol{J}(\boldsymbol{x}) = \frac{I(\boldsymbol{x}) - A}{\max(t'(x), t_0)} + \boldsymbol{A}, \tag{5}$$

Where $t_0 = (0.1)$ is a parameter that avoid dividing by small value.

III. PROPOSED METHOD

In He's method [1], the transmission medium $t'(\boldsymbol{x})$ is calculated by each local patch and its edge region is not smooth so soft-matting is used in order to smooth the image. But, Soft-matting is a time consuming and can not used for real time applications. In our method, we followed the following steps:

(1)Down-sampling: From He's method we observe that dark channel of haze image **I** has low spatial frequency. So, we calculated dark channel value with a down-sampled image inspired by [5].

(2)Estimation of pixel-wise dark channel image: We calculated the dark channel value using one pixel (1×1 patch) instead of 15×15 patch [1] to reduce the computation time without losing the spatial information. Hence, our proposed method do not need soft-matting process.

(3)Estimation of Robust ambient light: In order to reduce the computational time and to improve robustness, we calculate the ambient light using coarse to fine method.

3.1 Fast Computation with down-sampled image

The computational time is directly proportional to image size. We observed that the dark channel image has low spatial frequency. There is no significant effects on the estimated dark channel value even we used down-sampled image and then append it to original size after calculating the dark channel image and ambient light. In this method, the image is down-sampled to N/4×M/4 using box-averaging filter. Where N×M is the size of the original image. In order to enlarge the down-sampled image we used bicubic interpolation method.

3.2 Estimation of Pixel-wise dark channel image

We calculated the dark channel value using one pixel instead of 15×15 pixel to reduce the computational time without losing the spatial information such as edge. Although the calculation of dark channel value using one pixel is sensitive to noise, the noise is smoothen by down-sampling before the calculation. As we used one pixel (1×1 patch) for calculation of dark channels, there is no need for soft-matting process to smoothen the generated image, which is a time consuming process. In addition to this we used down-sampled image and one pixel for calculation of dark channel which reduce the computational time significantly.

Let us consider the value of direct light **J** in the dark channel as zero, then the first term of right hand side in eq. (3) can be eliminated. In our proposed method, the value of dark channel in observed light I calculated by 1×1 patch is larger than the conventional dark channel value calculated by 15×15 patch. Due to the removal of spatial minimizing, there a chance that the dark channel value in direct light **J** has small value (not a zero).

$$T_J(\boldsymbol{x}) = 1 - \gamma \frac{\left(\min_{c\in\{R,G,B\}}\left(\frac{I^C(\boldsymbol{x})}{A^C}\right) - \min_{x\in\Omega}\left(\min_{c\in\{R,G,B\}}\left(\frac{I^C(\boldsymbol{y})}{A^C}\right)\right)\right)}{\max_{x\in\Omega}\left(\min_{c\in\{R,G,B\}}\left(\frac{I^C(\boldsymbol{x})}{A^C}\right) - \min_{x\in\Omega}\left(\min_{c\in\{R,G,B\}}\left(\frac{I^C(\boldsymbol{y})}{A^C}\right)\right)\right)}, \tag{6}$$

$$t'(\boldsymbol{x}) = \frac{\left(1 - \omega \min_{y\in\Omega(\boldsymbol{x})}\left(\min_{c\in\{R,G,B\}} \frac{I^C(\boldsymbol{y})}{A^C}\right)\right)}{T_J(\boldsymbol{x})}, \tag{7}$$

Where γ is an adjusting parameter to decide the maximum dark channel value in direct light **J**. **Ω** represents the whole image.

The range of $T_J(\boldsymbol{x})$ is $1 - \gamma \leq T_J(x) \leq 1$. Since the dark channel value of 15×15 is smaller than 1×1 then $T_J(\boldsymbol{x})$ avoids the small $t'(\boldsymbol{x})$. Where ω is 0.95 and γ is 0.5 in our proposed method.

3.3 Estimation of robust ambient light

In He's method [1], initially they pick the top 0.1% brightest pixels in the dark channel of haze image **I**, and from these pixels they choose the highest intensity pixels. He's method ignores the small white object due to dark channel image which is estimated by 15×15 patch. In our proposed method, we calculated the dark channel by using 1×1 patch. In addition to this, He's method needs some time to sort the top 0.1% brightest pixels in the dark channel of haze image **I**. In order overcome this problem, we calculate the ambient light by using coarse to fine strategy in our proposed method. This method is shown in Fig. 1, we initially pick the top brightest pixels in the dark channel of the haze image **I** from the lowest resolution image to the highest resolution image (downsampled image by Sec. 3.1).

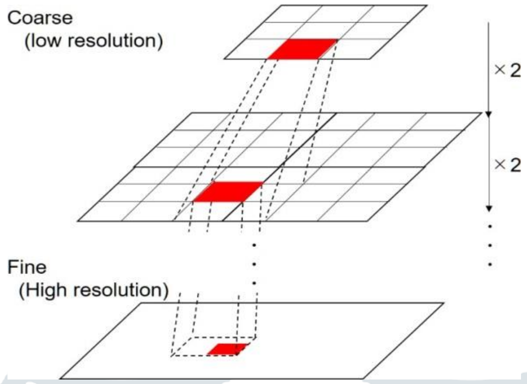

Fig.1 coarse to fine strategy for estimating ambient light **A**

(a) (b) (c)

Fig.2 comparison of the proposed method with He's method with real haze image. (a) input image, (b) He's method[1], (c) proposed method.

IV. EXPERIMENT

In this section, we compared our proposed method with He's method [1].The comparison of the haze removal images are shown in Fig. 2. It has been observed that the methods can remove the haze. The main difference is computational time, which is shown in the Table 1.

Table 1 Comparison of computation time in Matlab

Method	He [1]	Proposed method
512×512 pixel	11.295 sec	2.107 sec

V. CONCLUSION

In this paper, we proposed a fast haze removal method, which is an improving version of the dark channel model proposed by He et al. [1]. In this method, we reduced the computational time significantly by improving the method to estimate the dark channel. Our proposed dark channel estimation method used a down-sampled image and did not need a soft-matting process [2]. Experiments with haze images shown that our proposed method is faster and acceptable quality compared with He's method.

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