A New Single Image Dehazing Approach Using Modified Dark Channel Prior

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Abstract. Dehazing is a challenging issue because the quality of a captured image in bad weather is degraded by the presence of haze in the atmosphere and hazy image has low contrast in general. In this paper we proposed a new method for single image dehazing using modified dark channel prior and adaptive Gaussian filter. In our proposed method, hazy images are first converted in to LAB color space and then Adaptive Histogram Equalization is applied to improve the contrast of hazy images. Then, our proposed method estimates the transmission map using dark channel prior. It produces more refined transmission map than that of old dark channel prior method and then Adaptive Gaussian filter is employed for further refinement. The quantitative and visual results show proposed method can remove haze efficiently and reconstruct fine details in original scene clearly.

Keywords: Dark Channel, Image dehazing, Adaptive Histogram Equalization, LAB color space.

1 Introduction

Images of outdoor scenes are degraded as a result of known phenomena which take account of absorption and scattering of light by the atmospheric particles such as haze, fog etc. Haze removal is a critical issue because the haze is dependent on the unknown depth information. Dehazing is the process of removing haze in captured images and to reconstruct the original colors of natural scenes. If the input is only a single haze image, then problem is taken under constraint. Many methods have been proposed by using multiple images. In [1, 2] scene depths can be estimated from two or more images of the same scene that are captured in

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different weather conditions. S. Shwartz [4] and Y.Y. Schechner [5] removed haze using different polarization filters. The major drawback of these methods is that it requires multiple images for dehazing. But in some applications it is not always possible to obtain multiple images.

In order to overcome the drawback of multiple image dehazing methods, single image dehazing methods have been proposed [3, 6, 7]. Tan [3] proposed an automated method that only requires a single input image for dehazing. His proposed method removes haze by maximizing the local contrast of the images. The main drawback of Tan's proposed method generates overstretches contrast.

Fattal [8] proposed a refined image formation model that accounts for surface shading as well as the transmission function under the constraint that the transmission and surface shading are locally not correlated. The drawback of Fattal's method is that this approach cannot well handle heavy haze images.

He et al. [7] proposed a new method based on dark channel prior for single image haze removal and removed the drawbacks of [3,8] methods. In He et al. Proposed method , estimation of the thickness of the haze can be done directly by using dark channel prior and then soft matting algorithm is used to refine transmission value of each pixel to achieve high quality haze-free image. He[7] compared proposed method with various state-of-art methods and showed the superiority of proposed method. The main drawback of these methods is that their results are not much effective.

In our proposed method, dark channel prior [7] is further modified and improved contrast and can handle heavy hazy images. Section 2 reviews the related work. Section 3 presents the proposed methodology. Section 4 discusses result and discussions and section 5 describes the conclusion.

2 Related Work

In this section, we presented Optical model of hazy image [1,2,7] and dark channel prior that are closely to our proposed method.

2.1 Optical Model of Hazy Images

The attenuation of image due to fog can be represented as:

$$I_{att}(x) = J(x)\, t(x) \tag{1}$$

Where J(x) is input image, I(x) is foggy image, t(x) is the transmission of the medium.

The second effect of fog is Airlight effect and it is written as:

$$I_{airtight}(x) = A\,(1 - t(x)) \tag{2}$$

Where A is the Atmospheric light.

As fogy image is degraded by a combination of both attenuation and atmospheric light effect, it is expressed as:

$$I(x) = J(x)\, t(x) + A\,(1 - t(x)) \tag{3}$$

When atmosphere is homogeneous, transmission t(x) is represented as:

$$t(x) = e^{-\beta\, d(x)} \tag{4}$$

Where β is the scattering co-efficient of the atmosphere and d(x) is the scene depth of x. This equation describes an exponentially decaying function with depth and its rate is calculated using the scattering coefficient.

2.2 Dark Channel Prior

Statistical data of outdoor images reveal that at least one of color channel values (RGB) is often close to zero in some objects in a haze-free image [4]. The dark channel for an arbitrary image J can be expressed as:

$$J^{dark}(x) = \min_{y\in\Omega(x)} (\min_{c\in\{r,g,b\}} J^c(y)) \tag{5}$$

In this J^{dark} is the dark channel of J, J^c is the color channel,(x) is the patch centred at x.

2.3 Transmission Estimation

If J is a haze-free image, the dark channel of J is assumed to be zero.

$$J^{dark}(x) \longrightarrow 0$$

The transmission t(x) is calculated as

$$t(x)=1 - w \min_{y\in\Omega(x)} (\min_{c\in\{r,g,b\}} \frac{I^c(y)}{A^c}) \tag{6}$$

The variable w reduces the dark channel and it increases t(x) at a pixel x producing less subtraction in the restored image. Value of w is application dependent and it lies between 0 and 1.

2.4 Restoration of Input Image

After implementing Dark Channel prior and Estimation of transmission map, haze free image can be restored using:

$$J(x) = \frac{I(x)-A}{\max(t(x), t_o)} + A \tag{7}$$

A typical value of t_o is taken as zero or 0.1as it is prone to noise.

3 Proposed Methodology

In this section, we present our proposed methodology for improve contrast and quality of hazed images. The flow chart of our proposed method is shown in figure 3.The following steps are involved in our proposed strategy:

3.1 Convert RGB to LAB Color Space

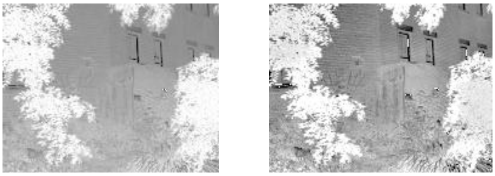
In our proposed method, we first convert input colored image to LAB color space. We observed that the fog presence can be better detected by looking at the LAB space of the image than RGB color model. Then split the image into L,A,B channel and Adaptive Histogram Equalization is applied on each channel to improve contrast because hazy images are of low contrast in general.

3.2 Estimation of Refined Transmission Map Using Dark Channel Prior

In section 2, we present the optical model of haze image. Using equations in section 2, we will calculate transmission map and refined transmission map. It is observed that our method will give lower values, resulting into higher values of t(x) because contrast of the images are improved and required lesser correction through equation(7). Figure1 showing our refined transmission map is more clear than old dark channel prior.

(a)Input haze image

(b) Image obtained using above steps



(c)Refined Transmission Map [7]

(d) Refined transmission map by our proposed method

Fig. 1 Comparisons of transmission Maps

3.3 Apply Histogram Stretching and Adaptive Gaussian Filter

Histogram stretching helps to stretching the range of intensity values of image uniformly and further improves the quality of images. Adaptive Gaussian filter preserve edge information of input hazy images and avoid generation of halo effects produced by dark channel prior and we get reconstruct fine details in original scene clearly as shown in figure 2.

(a) (b)

Fig. 2 (a) Image after *step B* and Input Image (b) Final Image

4 Experiment Results and Discussions

Our proposed technique has been tested on several different images. Figure 5 shows the input hazy images, dehazed images using classical definition of dark channel prior and images obtained by our proposed method. It is clear that the resultant images using the proposed technique are of good quality and contrast than the old dark channel prior. Not only visual comparison but also quantitative comparisons are confirming the superiority of the proposed method. Peak signal-to-noise ratio (PSNR), mean square error (MSE) and Normalised Absolute Error (NAE) have been implemented in order to obtain some quantitative results for comparison. PSNR is a mathematical measure of image quality based on the pixel difference between two images. Large value of PSNR indicates the high quality of image. PSNR can be calculated by using the following formula [9].

$$\text{PSNR}=10\log_{10}\left(\frac{R^2}{\text{MSE}}\right) \tag{8}$$

Where R represents the maximum variation in the input image and MSE represents the MSE between the given input image I_{in} and the original image I_{org} which can be obtained by the following[9]:

$$\text{MSE} = \sum_{i,j}(I_{in}(i,j)-I_{org}(i,j))^2 \tag{9}$$

Normalised absolute error (NAE) is a measure of how far is the output image from the original image. Low value of NAE means good quality of the image. NAE can be calculated using following formula [9]:

$$\text{NAE} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} |[f(i,j).f'(i,j)]|}{\sum_{i=1}^{M}\sum_{j=1}^{N} |[f(i,j)]} \tag{10}$$

Figure 4 shows the estimation of transmission map and calculated refined transmission map by our method and dehazed output image. The results in Tables 1, Table 2, Table 3 show the comparisons of PSNR, MSE, and NAE values.

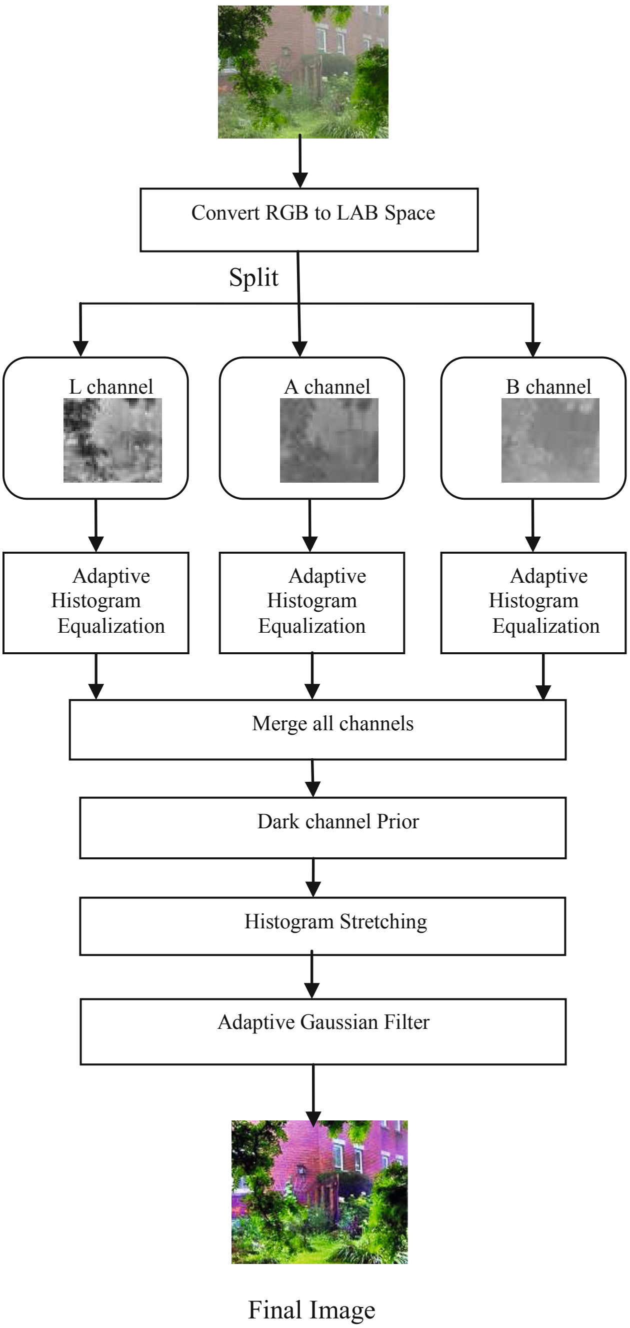
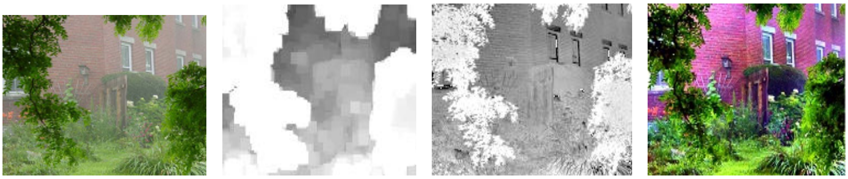


Fig. 3 The Flow Chart of Proposed Method



(a)Input Hazy Image (b) Transmission map (c) refined Transmission (d) Output Image

Fig. 4 Scanorio of Estimation Transmission Map and Refined Transmission Map

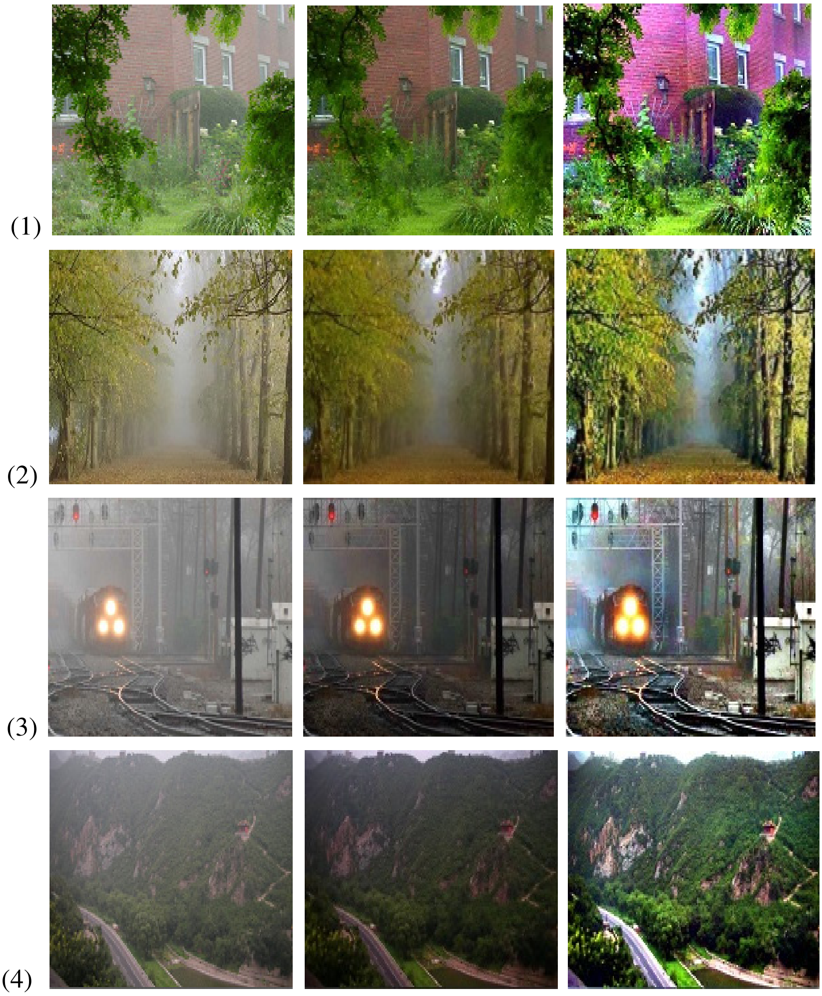


Fig. 5 (a) Original Images (b) Dark Channel Prior[7] (c) Proposed Method

(5)

Fig. 5 (*continued*)

Table 1 PSNR (dB) results for the proposed method for the input images shown in fig. 5(a) compared with the classical dark channel prior

		PSNR(dB)			
Techniques/images	(1)	(2)	(3)	(4)	(5)
Classical Dark Channel Prior [7]	64.3108	64.5548	59.7293	62.9965	61.9287
Proposed Method	67.1367	66.0319	66.3091	67.5062	65.9630

Table 2 MSE results for the proposed method for the input images shown in fig. 5(a) compared with the classical dark channel prior

		MSE			
Techniques/images	(1)	(2)	(3)	(4)	(5)
Classical Dark Channel Prior [7]	0.0289	0.0291	0.0692	0.0328	0.0314
Proposed Method	0.0105	0.0162	0.0152	0.0115	0.0165

Table 3 NAE results for the proposed method for the input images shown in fig. 5(a) compared with the classical dark channel prior

		NAE			
Techniques/images	(1)	(2)	(3)	(4)	(5)
Classical Dark Channel Prior [7]	0.2115	0.2587	0.4880	0.4420	0.3451
Proposed Method	0.1490	0.1913	0.1997	0.1788	0.2210

5 Conclusion

A new dehazed method is presented using modified dark channel Prior and Gaussian filter for the single haze image. In this paper, we improved contrast of haze images using adaptive Histogram Equalization on LAB color space. Then we calculated refined transmission map of the image and adaptive Gaussian Filter employed for preservation of edge information. Performance of the proposed technique has been compared with the classical dark channel technique. The experimental results show that the proposed technique gives better quality dehazed images. The quantitative measurements such as PSNR, MSE and NAE confirming the superiority of proposed technique over classical dark channel method.

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