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Haze Removal on Static Image by using Enhanced Techniques of Dark Channel Prior and Transmission Map Estimation

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Based on the natural phenomena, haze can be categorized as bad weather. The photo that taken during haze might result to the degrade of image scene. In the field of image processing, this research will cover some concepts and algorithms in order to overcome the hazy image problems. The fact is that the properties of haze can disrupt the scene of image. This paper was intended to present the enhanced techniques of dark channel prior and transmission map estimation in order to remove dense haze that scattered on a single image. It includes the operations of mathematics that can manipulate the results. The experiments have been conducted by comparing the qualitative analysis, together with the values of PSNR (Peak signal-to-noise ratio) and MSE (mean squared error). The values gained indicate the quality of output haze-free image. Based on this experiment, the results have been proven that the proposed algorithms was effective to perform the dehaze process.

Keywords: Single image, static image, image haze removal, image dehazing, steady weather.

I. INTRODUCTION

The quality of image scene can be degraded by the suspended particles in the atmosphere. The scattering of suspended particles can be occurred by a different kind of weather such as haze and rain. Haze is the example of steady weather meanwhile rain is known as dynamic weather (Garg *et al.,* 2004). So obviously that weather condition can be categorised into two types. This phenomenon can affect the surrounding in real-life, and even in the field of image processing task (Xu *et al.,* 2012). The type of weather affects by the recommended techniques, which will be discussed in this paper. The enhanced techniques of dark channel prior and transmission map estimation are only applicable for a steady weather, and not for a dynamic weather. Basically, the enhanced dehazing that proposed in this paper is suitable for image and video processing; however, the scope of work is only for a static image. The process of dehazing can be done in RGB colour channel. The experiment will be carried out by improving the quality, with less error and noise effect on the output of haze-free image.

Figure 1 and Figure 2 show the examples of input and output image from rain weather and

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haze weather respectively. It shows that Figure 1 is not suitable for this investigation. This is because the rain effect on image cannot be removed. However, Figure 2 is preferable for this experiment as it is acknowledged as steady weather (haze), where the haze on image can be removed.

(a) (b)

Figure 1. The example process of enhanced technique to remove rain on static image: not preferable. (a) Input of rainy image (b) Output of rainy image.

(a) (b)

Figure 2. The example process of enhanced technique to remove haze from static image: preferable. (a) Input of hazy image (b) Output of haze-free image.

Haze removal process is one of the challenging tasks in Image Processing field. It is due to the haze that depends on the unknown scene depth information (Gao *et al.,* 2014) and (Patel *et al.,* 2014). This problem occurs when there is only a single input of hazy image provided, so it has lack of information (Sun *et al.,* 2010). In order to overcome the problem, multiple images and extra information techniques are proposed in order to estimate the unknown depth information (Pei *et al.,* 2012). However, these processes might be costly to be implemented because it requires many information and extra hardware device in order to gain the accurate depth (Xing *et al.,* 2011). Therefore, a single image dehazing algorithm has been investigated in order to overcome the difficulty of multiple images and additional haze removal algorithms. The improvement is when the process can perform from a single input image without applying any other extra source of information, which it can reduce cost and provide with faster processing. Besides that, it allows obtaining the scene depth from a single of input image, with a simple of algorithm (Jin *et al.,* 2012). Since then, a lot of single image dehazing techniques have been approaches by many researchers, including the enhanced technique that proposed in this paper. Now the techniques of multiple images and additional dehazing are known as classical approaches. Recently, the single image dehazing techniques proposed have its own advantages and disadvantage, yet, still the improved process as to compare with the classical approach.

The objectives of this paper are: (i) to develop a modified algorithm of dark channel prior, (ii) to enhance a modified transmission map estimation algorithm, and (iii) to integrate the two modified algorithms in order to form a full technique of dehazing, which resulting the quality of haze-free image. Next, the motivations are described to remove dense haze on a static image, to improve the quality of haze-free image by reducing noise and error, and to improve the colour of image.

II. BACKGROUND

We begin by specifying the algorithm that will be used in the rest of this paper. In computer vision and graphics applications, the model of haze image formation is widely used to describe the overall factors that can lead the image to be degraded. Equation 1 shows an equation of the haze formation model:

$$H^c(x,y) = F^c(x,y) \cdot t(x,y) + \big(1 - t(x,y)\big)A^c \qquad (1)$$

Based on Equation 1, $F^c(x,y) \cdot t(x,y)$ refers to direct attenuation, meanwhile $\big(1 - t(x,y)\big)A^c$ is an airlight. The direct attenuation signifies the scene radiance and its decay in the medium, meanwhile the airlight results from previously scattered light and leads to the shift of the scene colours. The direct attenuation is a multiplicative distortion of the scene radiance, whereas the airlight is an additive one. This haze optical model has been employed in most works of single image dehazing. Next, $H^c(x,y)$ shows the hazy image with observed intensity and $F^c(x,y)$ reconstruct by the scene radiance (haze-free image recovering). A is the global atmospheric light, and $t(x,y)$ is the transmission map that refers to the medium transmission indicating the portion of light that is not scattered and reaches into the camera. The major goal of a single image dehazing is to recover the$F^c(x,y)$, $t(x,y)$ and A from the haze-free image, $H^c(x,y)$, which is an under-constrained problem. In order to get clear information regarding to the haze image formation model, the illustration has been drawn as shown in Figure 3:

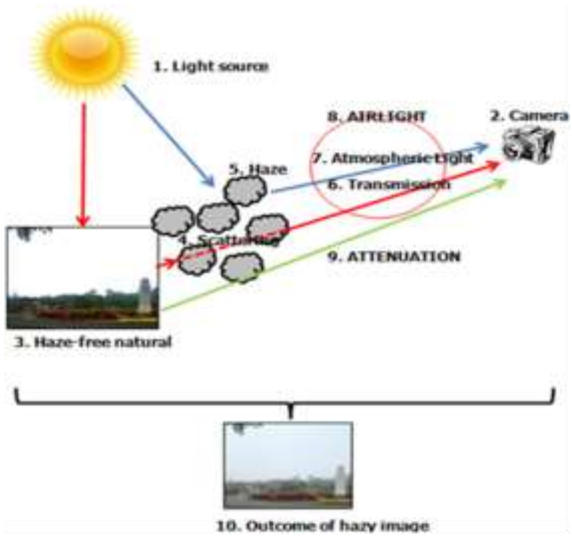

Figure 3. Haze Image Formation Model

In the next section, we will describe the enhanced technique of haze removal, which consist of modified of dark channel prior and the modified of transmission map estimation.

A. Enhanced Haze Removal Technique

The idea of the enhanced haze removal technique is based on the integration of modified dark channel prior and modified transmission map estimation. Both of the techniques are inspired by Kaiming technique and Gibson technique. So the experiment test will be conducted by comparing with the two previous techniques.

First of all, the haze image formation model will be recognized. It will be used as an input image. Next, the input image will undergo the process of modified dark channel prior. The process will be continued by estimating the airlight and transmission map. After that, the image will go through the post-processing as to improve the contrast enhancement. Histogram equalization will be applied to the post-processing technique. From here the integration process will occur, following by the image that will undergo through the original dark channel. In order to improve the edges of objects on the scene image, the median filter will be applied. After the process of filtering has been done, airlight will be estimated. Then, the image will undergo through the modified of transmission map estimation. In order to improve the colour of output image, gamma correction will be applied to the post-processing technique.

Figure 4 shows the architecture of a full process for enhanced dehazing technique, which has been elaborated in the previous paragraph:

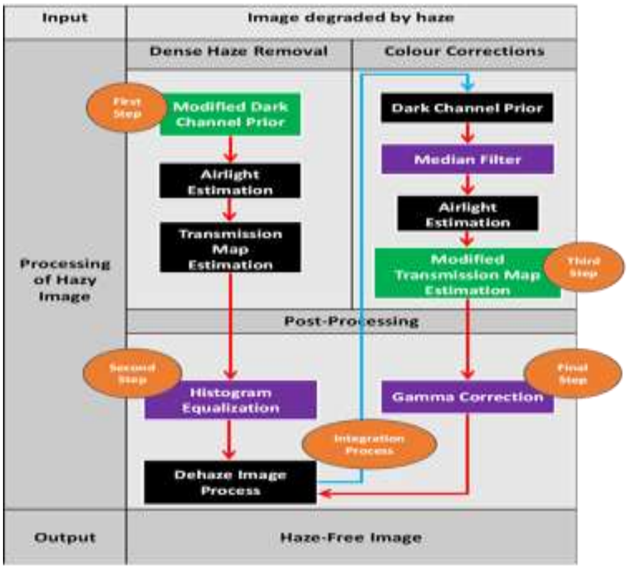

Figure 4. Architecture of Enhanced Dehazing Technique

In the next section, we will present the modified algorithm of dark channel prior.

B. The Modified of Dark Channel Prior Technique

The fundamental of the original dark channel prior equation is derived from the haze image formation model. Then it will be modified to form as shown in Equation 2:

$$F^{DarkModified}(q) = min(max(F^{c}(p)))^{2} \quad (2)$$

This technique allows the haze effect removal and adjusts the image intensity by applying the histogram equalization technique. This enhancement is capable to produce a quality of output image, where it manages to get the lowest value of noise and error as to compare with Kaiming technique and Gibson technique. The results of modified dark channel prior have led to increase the brightness on image. So the contrast enhancement by histogram equalization will be applied. Histogram equalization can reassign the intensity values of pixel in the input image. Hence the output image will be fully covered by the pixel distribution, which it can increase the clearness and whiteness of image uniformly. However, this process has disturbed the sky region because the scene has mixed up with the white colour of cloud region. All the experiment results will be discussed in the next section.

B. The Modified of Transmission Map Estimation Technique

Basically, the original transmission map estimation is derived from the previous step of dark channel prior. After that, the equation will be modified as shown in Equation 3:

$$t^{Modified}(p) = \frac{\sqrt{1-\left[w\left(med\left(min\left(\frac{H^c(p)}{A^c}\right)\right)\right)\right]}}{a} \times 255 \qquad (3)$$

This enhancement is important to improve the image colour. Besides that, the role of this contribution is to adjust the transmission of bright regions, which resulting the better of transmission map. The median filter will then be applied for edge restoration. At this point, the colour of dehazed images seems to look more natural. In order to improve and control the overall brightness of an image, the gamma correction technique will be applied. It is aimed to correct the level of gamma on image. However, when the gamma level of the image is not properly corrected, the output will bleached or the effects can be darkened. The constant value of gamma correction will be set up in the experiment. However, the quality results have been interrupted due to some error and noise that exists on image. In order to overcome the problems, a modified transmission map estimation technique and a modified dark channel prior technique will be integrated to obtain better results of output image. All the experiment results will be discussed in the next section.

III. RESULTS AND DISCUSSION

In this section, we compare our results with Kaiming technique and Gibson technique. The final results are from the integration of the two modified techniques. The experiments are carried out in order to compare the results of PSNR test and MSE test. The improve quality is based on the highest results that obtained by PSNR test, which means the image has contain with less noise. However the MSE test is depends on the lowest results, which it shows that the image contains with less error.

Table 1 shows the results gained by PSNR test for 10 samples of dataset. It shows that our technique provides good results compare to the other techniques. While the next is Table 2 shows the results experiment of MSE test for the same samples of the dataset. This technique has also succeeded in producing good results compared to other techniques

Table 1. Experimental Results of PSNR Test

Image	PSNR Test (dB)		
	Kaiming Technique	Gibson Technique	Enhanced Dehazing Technique for Dense Haze
1	12.23	13.72	15.13
2	12.08	16.40	17.07
3	11.80	14.36	15.74
4	12.74	16.44	17.10
5	10.86	13.61	16.46
6	12.16	15.22	15.83
7	12.68	10.91	14.14
8	15.96	15.50	16.15
9	15.75	13.78	15.77
10	15.59	14.64	16.02

Table 1 refers to the results gained by PSNR test. Image 4 generates the better PSNR result with 17.10dB. In the meantime, Kaiming technique and Gibson technique only manage to produce with 12.74dB and 16.44dB respectively. The lowest result delivered by this proposed technique is 14.14dB (Image 7), however, the result is still the best as to compare with Kaiming technique (12.68dB) and Gibson technique (10.91dB).

Table 2. Experimental Results of MSE Test.

Image	MSE Test (dB)		
	Kaiming Technique	Gibson Technique	Enhanced Dehazing Technique for Dense Haze
1	3920.13	2785.07	2009.76
2	4055.83	1500.38	1285.25
3	4331.20	2403.02	1748.81
4	3484.90	1487.36	1277.50
5	5375.65	2856.35	1480.93
6	3984.55	1971.53	1713.70
7	3533.18	5311.15	2524.86
8	1663.26	1845.59	1591.45
9	1744.08	2743.19	1736.62
10	1810.78	2249.87	1636.99

Table 2 displays the results obtained by MSE test. The result of Image 4 produced by the proposed technique shows the better amongst the other technique, which is 1277.50dB. Meanwhile, Kaiming technique and Gibson technique manage to produce with 3484.90dB and 1487.36dB respectively. Then, the lowest result that produces by proposed technique is 2524.86dB on Image 7, yet, still valid as the great results as to compare with the two techniques that resulting with 3533.18dB on Kaiming technique and 5311.15dB on Gibson technique. Finally, the comparison images from a sample of dataset will be figured out in Figure

5:

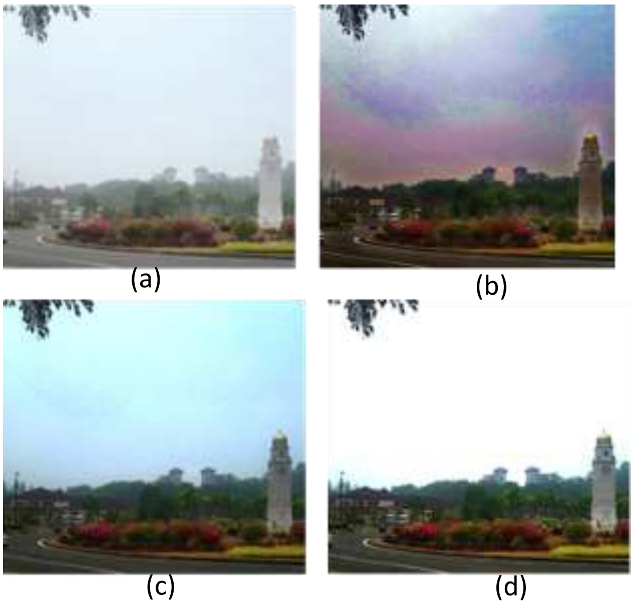

Figure 5. Haze Removal Process. (a) Input of hazy image. (b) Output of Kaiming technique. (c) Output of Gibson technique. (d) Output of proposed technique.

Figure 5 shows the images of a chosen dataset. Figure 5(a) is the original input of hazy image, in the condition of dense haze. Then Figure 5(b) shows the output image from a modified of dark channel prior technique. The image looks unsatisfied, so we manage to proceed for the next step, which is to undergo the process of modified transmission map estimation. The result image from a technique of modified transmission map estimation has shown in Figure 5(c). Finally, the two techniques will be integrated to produce the better scene haze-free image as to compare the previous two images (shown in Figure 5(d)).

IV. CONCLUSION

This enhance technique is able to remove the dense haze effects from the degraded image. Besides that, the original colour of image scene has been improvised. By considering the haze removal process, the proposed technique can also handle the contrast enhancement and gamma correction by undergoing the post-process. The recovered image from this technique shows with no block or halo effects by comparing with other techniques. However, this technique is not suitable for detail enhancement process, where it can only restore the edges of object on image. The quality of images is performed based on the value of PSNR and MSE test results.

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