Scattered Particles Removal in Single Image for Technology of Hologram

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Abstract

Scene image captured by vision devices usually occluded by scattered atmospheric particles. The quality of image usually corrupted by this problem. Recent researches usually do the image enhancement and recovery method to solve the problem. Doing image enhancement usually eliminate some potential scene information accidently. Previous researchers did the recovery methods to remain the potential information physically. They did veil estimation, depth transmission estimation and reflectance layer estimation to remove the scattered particles. By doing this, image may contain unreliable value added in veil estimation and transmission. So that the scene of image structure was disturbed. This research did the potential illumination estimation that influence the scattered particles occurred in the image. Result of the experiment proved that this method to reliable value to remove in the image was remained by Structure Similarity Index Matrix(SSIM).

Keywords: Haze removal, Scattered particle, Illumination information, Hologram

1. Introduction

During the bad weather condition occurred, most of the outdoor vision systems such as object detection, tracking, and recognition will obscure by the turbid medium like haze, fog or smoke. The quality of capturing scene image may reduce by the atmospheric scattering and absorption [1-3].

Scattering particles would be bright out depends on the scene depth and the illuminance received by the imaging device that attenuated along of sight line [4]. Hence, the scattered particles related behaviour of degradation varies spatially and the source of light that scattered in the atmospheric scene will form the veil as shown in the physical scattered particles model. Due this, the ambient light may reflect the sight line across the object [5]. Figure 1 is the physical scattered particles model that shows the relation of direct attenuation and air light during scattered particles occurred.
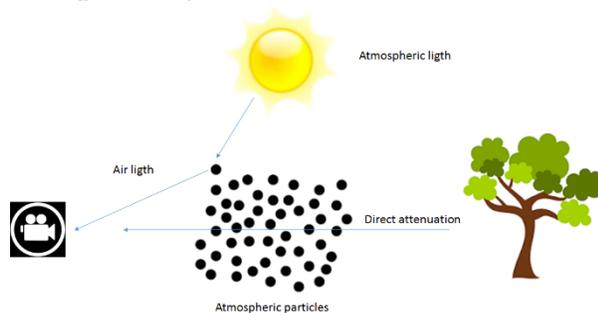

Fig.1: Scattered particles model

During the process to display hologram image, the scene has to be clear without any scattered information due to the transition colour and matrix within the type of hologram projector [6, 7]. Most of the scene was distorted by scattered particles when the image was projected. Then, the display image had been manually setting to improve the vision. Hologram visualization system is sensitive to low contrast of image. So that the quality of the image projected by low contrast make the scene fuzzy and hard to visualize [8].

This paper is organised according to next section 2 that describe the retinex theory, scattered particles model and the hologram. Most of the related works about the scattered particles removal will be explained in this section in detail. In the section 3, the propose idea of scattered particles removal algorithm based on the illumination information will be discuss accordingly. Next, in the section 4 will describe about the experiment results. Finally, the discussion and conclusion about the work will be explained in section 5.

2. Related works

2.1. Retinex Theory

The relation between the illumination and the reflection in the image is the image intensity that follow the retinex theory. This theory can be describing the relation as an equation in (1):

$$I(x,y) = L(x,y) \cdot R(x,y) \qquad (1)$$

Where $I(x,y)$ is image intensity, $L(x,y)$ is weight of the illumination, and $R(x,y)$ is the reflecting factors in the single image.

The characteristics of the scattered particles that occurred in the image would be estimated by Gaussian distribution. But, some of the colour information may eliminate in Gaussian filter processing that cause colour reduction [6]. Hence, the Bilateral filter is use as the treatment to overcome image luminance component. Usually, this method is easy to use and programmable but the edges may blur according to the filtering process, time expensive and reducing colour appearance [7].

2.2. Scattered Particles Model

The research about scattered particles removal is attracting most of the researcher's attention widely. Several number of the methods were proposed to restore a single scattered particles image gradually without referring any other information. Fatal used the local window and graphical model to overcome the scattered particles image. This method may restore the image with good result using separating uncorrelated fields, but high computation intensive [8, 9]. Differ than the method used by Tan that did not remain the performance in every saturated scene. But, this method stables and easy to apply by maximising the contrast. Therefore, this method can work fine on both colour and grayscale images [10]. However, this method uses high computation and reduce the processing speed. Than Ancuti proposed the fusion strategy that derived from the two original scattered particles image input. This method uses the utility and mix difference image enhancement tool as the fusion technique, but the colour of the image is not genuine and the contrast may miscalculated [11, 12].

The interesting method uses the prior knowledge information named the dark channel prior is proposed by He to remove scattered particles [4]. This method observes the most local patches in outdoor images that free from noise and believe that this image contains some pixels that have intensity is lower than other pixels. This pixel may at least one of the RGB channel intensity. This intensity may represent as the thickness of the scattered particles. However, this method will produce halo and artefacts because of using the local patch windows. Li, Fu and Wang proposed the enhancement of matting to refine the transmission map, but this more effective with colour than grayscale [13-15]. Then, Tripathi and Mukhopadhyay proposed the anisotropic diffusion to refine transmission map accordingly. This method based on low value of the transmission, the worst gradient area uses to be multiply by the highest coefficient number to improve visibility. This method remains the colour to avoid the result may distort from previous patch. This will effective improve to inverse the transmission and in the gradient domain. Then, multiscale is used to recover the visibility with small transmission and remain the contrast. But, altering the gradient will make low dynamic range become high dynamic range. Therefore, the image may become dark and over saturation.

In addition, this method uses the simple linear compression equation but may become blurring in several parts. Furthermore, this method is high computation cost and complex. Even though, the output may artefacts free but the image may contain colour cast. This would be happened when the transmission map value is near to atmospheric light. Therefore, the colour cast may bright out more than the sky region. According to dark channel prior and the scattered particles model, the brightness of the infinity scene is referring to the global atmospheric light. This is important reference as the parameter to restore the image contrast. The image may become darker as the reference estimation global atmospheric light is more high than the normal atmospheric scene.

Hence, halo or oversaturation will occur in the sky region due to the estimation value is lower than the exact light value. Figure 2 shows the difference experiments to estimate the global atmospheric light with difference methods. As this matter, Xiao et al. select the brightest pixels (0.2 %) in the dark channel to enhance the accuracy of the atmospheric light. But, some of the brightest pixels in white objects may become the source of the global atmospheric light value. Yeh et al. tried to the range of atmospheric light by choosing the top 0.1% brightest value in dark channel and the top 30% darkest value in the bright channel, then calculating the estimation of the atmospheric light [16].

Fig.2: Input (top-left), He Method (top-right), Tan method (bottom-left) and Tarel method (bottom-right)

The performance of the scattered particles removal methods is improving gradually. However, the effectiveness of estimation two major factors is critical to define as to calculate the more accurate global light estimation and transmission map estimation from the right colour and brightness region that maximised the restoration. The intention of this study is organise as follow. The well planning to estimate the global atmospheric light as the veil from the scattered particles image to overcome the fatal from occurred with normalize the global illumination and local atmospheric light to avoid halo and artefacts affected the scene. After the local atmospheric light veil and the transmission map is well calculating, the reflection component in the RGB channel will be constructed. Therefore, this method will recover the contrast according to this two major factors accordingly.

2.3. Setting Up of Hologram Technology

In this research, the concept of Shallow Depth of Field has been implemented since the advancement and advantages of this technology that might offered. The concept of Shallow Depth of Field was implemented for image processing specifically for cleaning the data/ image process [17]. The process can be referred in Figure 3.0 below. Based on the objectives and problem statements stated earlier in this research, the image/data will be extracted especially on the scene information and later will be processed in terms of background segmentation and object segmentation. The end result will be in Digital Hologram Image Processing (DHIP) image and end result will be the create focused images [18].
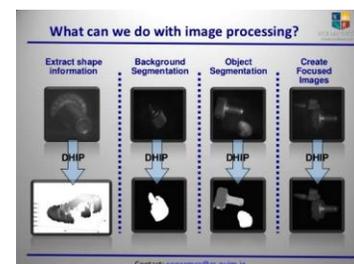

Fig.3: The process of extraction, segmentation and focused images.

3. Proposed Methodology

This study will follow the common equation to describe image noise. The equation is referred as equation (2).

$$I(x,y) = J(x,y).t(x,y) + A.\left(1 - t(x,y)\right) \qquad (2)$$

where $I(x,y)$ is the observation scene intensity that contain scattered particles, while $J(x,y)$ is the common scene radiance, this will be representing the reflection of the radiance to the object across line to the observer. A is the global atmospheric radiance, and $t(x,y)$ is the transmission map as well as the scene light depth that captured by camera. The intention of this model is to recover $J(x,y)$, A and $t(x,y)$ from $I(x,y)$ as the key factor. Therefore, the restoration process will recover A and $t(x,y)$ as first step then combination of this estimation become the restoration product in the equation (2) to restore $J(x,y)$.

The part of $J(x,y)\,t(x,y)$, in the right term is representing direct attenuation and second part $A\,(1 - t(x,y))$ is refer as an air light. Therefore, direct attenuation is referred as the scattered particles free condition and air light depending to scene depth contour that will affect scene's colour fading.

This method is follow the optical model according to the Koschmieder's law derivation and the equation is simplified as equation (3)

$$I(x,y) = A.\left((R(x,y) - 1).t(x,y) + 1\right) \qquad (3)$$

Where $I(x,y)$ is the scattered particles image intensity, A is the global atmospheric light brightness or the maximum RGB colour model intensity, $R(x,y)$ is the reflection object intensity and $t(x,y)$ is the transmission map or scene depth across the background to the foreground intensity. This equation derived from the common model as the retinex theory. As the condition that no scattered particles, the equation is usually derived as equation (4).

$$I(x,y) = A.1 \qquad (4)$$

This condition will be occurred since the $t(x,y)$ is ∞ or 0. Then the equation in (3) can be derived and goes to equation (5) as

$$I(x,y) = A.\left(R(x,y).t(x,y) -. t(x,y)\right) + 1) \qquad (5)$$

From the equation (5), this equation can be derived as equation (6) when α is the minimum RGB colour space intensity value.

$$I(x,y) = A.\left(\alpha + 1\right) \qquad (6)$$

This α can be refer as the equation (7)

$$\alpha = (R(x,y) - 1).t(x,y) \qquad (7)$$

According to white light veil in the scattered particles image and clear image, the scene brightness is equally same. Therefore, the equation of scattered particles image can be derived as energy equation as equation (8)

$$A_{Clear} = A_{Haze} - A_{Haze}.\alpha \qquad (8)$$

Hence, this optical model based method already performed well and to obtain the improvement of colour variety. This method used the Contrast-limited adaptive histogram equalization (CLAHE). CLAHE is well known image enhancement to enhance the image contrast locally. This method can operate with 8×8 image area as a tiles. Each contrast tile will enhance and the result histogram will match the flat histogram. The neighbouring tiles will combine using bilinear interpolation to remove addition boundaries. The result's contrast surrounding the homogenous area will avoid to amplify noise or additional structures such as object textures. This noise might be existing during this process in the image [19].

4. Evaluation of Experiment

This study is required the corresponding bench marks data set as the ground truth to evaluate the performance of the method regarding to the restoration process for the scattered particles image. But, as this study difficulty to get the ground to compare the state of the art. This study uses four quantitative evaluations to assess this proposed method and compare with these state of the art methods. There are the new visible edges ratio (ϵ), the gradient ratio (g), the percentage of number of saturated pixels (Σ), and structure similarity index metric (SSIM). The Hautire et al. proposed the first three metrics as the blind assessment to evaluate the performance. The metric ϵ is to evaluates the ability of the scattered particles removal method to restore and recover the edges that will not visible in the original image but the edge will visible after the restoration image; the higher value of ϵ shows the better performance and quality of the scattered particles removal method because the clear images have more contrast than the scattered particles images. The gradient ratio (g) is refer to the existing contour magnitude. The best performance is referred to the darkest as the high value of the gradient. The metric Σ indicates the percentage of pixels' existence that become black or white completely after the restoration process [20]. The evaluation of the structure image referred by the SSIM. The close value to 1 is the best performance that indicate low structural disturbance. All these evaluations tested to the following three images as the doll, roof and the New York with difference texture. The following figure 4, figure 5 and figure 6 are the images used in this study.

(a)Input

(b) Output
Fig. 4: Doll

(a) Input

(b) Output
Fig. 5: Roof

(a) Input

(b) Output
Fig. 6: New York

Table 1: The Image Enhancement Performant Evaluation

Method	Doll			
	ϵ	g	Σ	Ş
Tan	**1.6**	**2.89**	**0**	0.42
Tarel	1.3	2.01	0.1	0.48
He	1.15	1.78	0.23	0.53
Proposed	1.17	1.92	0.21	**0.89**
Method	Roof			
	ϵ	g	Σ	Ş
Tan	**2.12**	**3.03**	**0**	0.31
Tarel	2.01	2.78	**0**	0.53
He	1.75	2.01	0.09	0.62
Proposed	1.78	2.12	**0**	**0.92**
Method	New York			
	ϵ	g	Σ	Ş
Tan	0.84	1.26	0.2	0.39
Tarel	0.99	**1.43**	0.1	0.48
He	1.01	1.33	0.09	0.53
Proposed	**1.12**	1.27	**0**	**0.72**

5. Discussion and Conclusion

According to the experiment's analysis, the best performance result must follow the two conditions. First, the contrast must be higher than the original scattered particles and second is the image must have the good structural similarity with close to the original scattered particles image. Hence, this study need to compute the relation contrast level and the structural similarity. Regarding to the contrast level, the best performance is the Tan method as shown in the table 1. This method best for the image Doll and Roof but not the New York because of the maximising contrast in the low light condition is become worst to Tan's method. In the low light condition, the best method is marks as proposed method that utilise the efficiency of the illumination information. This result determine that proposed method closed to remain the structural similarity by reducing to disturb uncorrelated relation and remain the light source condition. As Tan's method is intent to maximise the contrast, this method would be able to improve the edge of the image but not the variety of the image colour. The proposed method nearly remains the zero for the saturation percentage because this method enhances the ability of the light reflection rather than the contrast to avoid eliminate colour information accidently. Therefore, all the SSMI evaluation is best for the proposed method.

Acknowledgements

References

[1] S. G. Narasimhan and S. K. Nayar, "Interactive (de) weathering of an image using physical models," in *IEEE Workshop on Color and Photometric Methods in Computer Vision*, 2003, p. 1.

[2] S. G. Narasimhan and S. K. Nayar, "Contrast restoration of weather degraded images," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 25, pp. 713-724, 2003.

[3] Y. Y. Schechner, S. G. Narasimhan, and S. K. Nayar, "Polarization-based vision through haze," *Applied Optics,* vol. 42, pp. 511-525, 2003.

[4] K. He, J. Sun, and X. Tang, "Single image haze removal using dark channel prior," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 33, pp. 2341-2353, 2011.

[5] R. T. Tan, "Visibility in bad weather from a single image," in *Computer Vision and Pattern Recognition, 2008. CVPR 2008. IEEE Conference on*, 2008, pp. 1-8.

[6] B. Xie, F. Guo, and Z. Cai, "Improved single image dehazing using dark channel prior and multi-scale Retinex," in *Intelligent System Design and Engineering Application (ISDEA), 2010 International Conference on*, 2010, pp. 848-851.

[7] J. Zhou and F. Zhou, "Single image dehazing motivated by Retinex theory," in *Instrumentation and Measurement, Sensor Network and Automation (IMSNA), 2013 2nd International Symposium on*, 2013, pp. 243-247.

[8] R. Fattal, "Single image dehazing," in *ACM transactions on graphics (TOG)*, 2008, p. 72.

[9] R. Fattal, "Dehazing using color-lines," *ACM Transactions on Graphics (TOG),* vol. 34, p. 13, 2014.

[10] M. Sulami, I. Glatzer, R. Fattal, and M. Werman, "Automatic recovery of the atmospheric light in hazy images," in *Computational Photography (ICCP), 2014 IEEE International Conference on*, 2014, pp. 1-11.

[11] C. O. Ancuti and C. Ancuti, "Single image dehazing by multi-scale fusion," *Image Processing, IEEE Transactions on,* vol. 22, pp. 3271-3282, 2013.

[12] C. O. Ancuti, C. Ancuti, and P. Bekaert, "Effective single image dehazing by fusion," in *Image Processing (ICIP), 2010 17th IEEE International Conference on*, 2010, pp. 3541-3544.

[13] Z. Fu, Y. Yang, C. Shu, Y. Li, H. Wu, and J. Xu, "Improved single image dehazing using dark channel prior," *Systems Engineering and Electronics, Journal of,* vol. 26, pp. 1070-1079, 2015.

[14] B. Li, S. Wang, J. Zheng, and L. Zheng, "Single image haze removal using content-adaptive dark channel and post enhancement," *Computer Vision, IET,* vol. 8, pp. 131-140, 2014.

[15] [15]J.-B. Wang, N. He, L.-L. Zhang, and K. Lu, "Single image dehazing with a physical model and dark channel prior," *Neurocomputing,* vol. 149, pp. 718-728, 2015.

[16] C.-H. Yeh, L.-W. Kang, C.-Y. Lin, and C.-Y. Lin, "Efficient image/video dehazing through haze density analysis based on pixel-based dark channel prior," in *Information Security and Intelligence Control (ISIC), 2012 International Conference on*, 2012, pp. 238-241.

[17] L. Hesselink, "Digital image processing in flow visualization," *Annual Review of Fluid Mechanics,* vol. 20, pp. 421-486, 1988.

[18] T. Okugawa and K. Hotate, "Real-time optical image processing by synthesis of the coherence function using real-time holography," *Ieee Photonics Technology Letters,* vol. 8, pp. 257-259, 1996.

[19] M. F. Al-Sammaraie, "Contrast enhancement of roads images with foggy scenes based on histogram equalization," in *Computer Science & Education (ICCSE), 2015 10th International Conference on*, 2015, pp. 95-101.

[20] N. Hautière, J.-P. Tarel, and D. Aubert, "Towards fog-free in-vehicle vision systems through contrast restoration," in *Computer Vision and Pattern Recognition, 2007. CVPR'07. IEEE Conference on*, 2007, pp. 1-8.