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Single Image Haze Removal via Accurate Atmosphere Light

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Abstract

One of the uncontrollable problems of the bad weather conditions is the haze. The haze causes poor visibility image. It attenuates the contrast and the color of the image. It creates major problems in some applications in the fields of computer vision and image processing such as intelligent vehicles, surveillance system and satellite imaging. In order to obtain the clear images, haze removal is inevitable. In this paper, we introduce a new method for haze removal. Our experiments show that the atmosphere light is the key rule for solving the problem of haze images. This paper suggested new formula to compute the atmosphere light directly, then computes two values for the atmosphere light and choose the maximum one between them. We compute the transmission map depending on the accurate value for atmosphere light which makes suggested method one of the fast methods. New formula suggested to enhance the local contrast of the image. The proposed method applied on more than 3000 haze images. The proposed method measures the quality for de-hazed images by using many quality criteria (reference quality and blind quality). The proposed method has acquired good results comparing with other methods.

Keywords: Haze image, de-hazing, atmosphere light, image processing, local contrast.

INTRODUCTION

The physical features of particles in the atmosphere affected by the bad weather condition. Bad weather affects shape, size, and concentration of the particles. These physical features determine the total scattering coefficient in the atmosphere. Each particle in the atmosphere absorbs and scatters the reflection ray from the sense. The particles form haze, fog, cloud, rain and snow according to their properties in the atmosphere.

Haze is one of the problems of the bad weather conditions. The haze images lose the color fidelity and contrast. The de-hazing image became an important task in order to obtain the clear image. The de-hazing is a challenging task as the density of the haze is different from place to place and due to weather condition at the moment of capturing the scene[1].

In recent years, de-hazing technology based on a physical model for the single image has achieved significant progress and most of methods were good to solved the problem of hazing in many ways, but there are no one regards as a perfect way yet and their efforts fell greatly short of what we really need.

Some of the methods which have a significant role in explaining the problem and develop solutions for it are:

He, Kaiming [2]: proposed method which is a kind of an observation statistic to clear images. It supposes that in clear images the most intensities of pixels in local patches have a very low intensity at least in one color channel, by this idea the atmosphere light and the transmission map can be computed directly, then refine the transmission map by using a soft matting.

Fattal, Raanan 2014[3]: introduced a new method relies on a general system in small patches image. The pixels usually appear in RGB color space one-dimensional distribution, called color-lines. It creates a local model that explains the color-lines in the haze image and uses it in order to estimate the scene transmission relying on the lines' offset from the origin. At patch run RANSAC procedure to find a line and test it if that line can be a color line or not, after that run Markov random to regularize the transmission for the image.

Zhenfei, Gu 2017[4]: introduced de-hazing method based on the following steps:

Step1: Developing the atmospheric scattering model. Step2: Dividing the hazy image to the scenes according to the haze density similarity. Step3: Defining a function weight for improving the accuracy of estimation for the atmospheric light. Step4: Suggesting the average saturation prior model and mixing it with the developed model, then find the scene atmospheric scattering coefficient and gets the scene albedo.

PHYSICAL MODEL FOR HAZE IMAGE

The haze is one of a bad weather conditions problems leads to constitute two phenomena in the atmosphere: The direct Attenuation and Air-light [5][1].

$$Haze\ image = Direct\ attenuation + \text{Air-light} \quad \textbf{(1)}$$

$$H(x,y) = K(x,y) * M(x,y) + A * \big(1 - M(x,y)\big) \quad \textbf{(2)}$$

$$M(x,y) = e^{-Sd(x,y)} \qquad \textbf{(3)}$$

Were $H(x,y)$ is the haze image with coordinates x,y, $K(x,y)$ is the clear image, $M(x,y)$ is the transmission map, $d(x,y)$ is the distance between the location of the pixel (x,y) in a scene and the camera, A is the global atmosphere light and S is the scattering coefficient.

PROPOSED METHOD

In this paper we suggest a new method for removing haze from imageaccording to the following steps:

1. Image filtering.
2. Estimating the Low-haze channel.
3. Determining the value of white color in sky region.
4. Computing the values of first and second atmosphere lights, then choosing the maximum one between them.
5. Computing the values of transmission map.
6. Recovering the de-haze image.
7. Improving the local contrast.

Image in figure (1) used to help in explaining the above steps.

1. Image filtering

At this step we suggested to use average filter. The strength of average filter depends on the size of the filter window, where the small size widow dose not remove noise effectively, while the large size widow remove noise more effectively but blur the image details, for that we need to trade-off between the noise removal and details preserving. We suggested a window with size 5*5 which gives the best results for smoothing the haze image. Figure (2) shows the smooth image.

Figure 1: Haze image.

Figure 2: Smooth image.

2. Estimating the Low-haze channel

Generally, existing haze in image causes changing of the pixels' intensity for the entire image. The changing depends on the transmission map $M(x,y)$. The model for removing haze (equation (2)) can be rewritten as: $M(x,y) * \big(A - K(x,y)\big) = A - H(x,y)$ **(4)**

Equation (4) expresses that when the haze generated at pixel (x,y) reduces the distance between the atmosphere light and the intensity of pixel at location (x,y) (see figure 3). So the distance:

$$D = A - \mathit{The\ intensity\ of\ pixel}\ \text{in location}(x,y) \qquad \textbf{(5)}$$

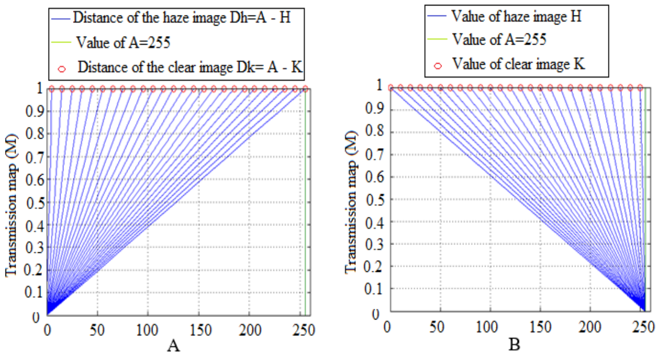

Figure 3: Imitation of effect the haze on the image. **A-** increases the intensity of image. **B-** reduces the distance between the atmosphere light and the pixels. (assume the value of the atmosphere light equal to 255).

By dividing the two sides of equation (4) by (A), we get: $M(x,y)\left(1-\left(\frac{K(x,y)}{A}\right)\right) = 1-\left(\frac{H(x,y)}{A}\right)$ **(6)**

From equation (6) we conclude that the haze restrict the distance between 1 and the ratio (R) (the intensity of pixel (x,y) / the atmosphere light).

If we assumed the value of A=255, then the range of (R) will be [0 1].Where R in haze image is R_h and in clear image is R_k.

The distance $D_R$is measured as the following:

$$D_R = 1 - \frac{\mathit{The\ intensity\ of\ pixel}\ \text{in location (x,y)}}{\text{The atmosphere light (A)}} \qquad \textbf{(7)}$$

The distance in haze image is: $D_{Rh} = 1 - \left(\frac{\mathrm{H(x,y)}}{\mathrm{A}}\right)$ **(8)**

The distance in clear image is:

$$D_{Rk} = 1 - \left(\frac{\mathrm{K(x,y)}}{\mathrm{A}}\right) \qquad \textbf{(9)}$$

The effect of haze on image depend on the value of R (see figure 4).

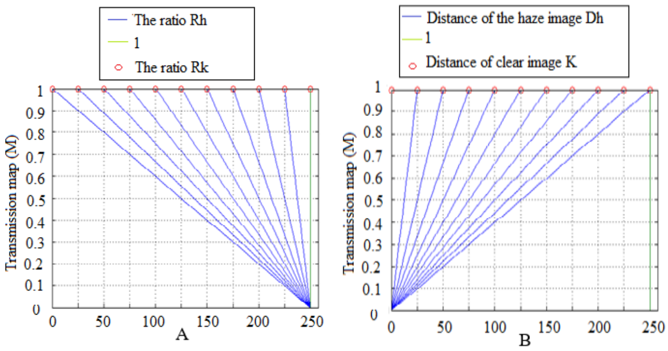

Figure 4: Imitation of effect the haze on the image depending on R.
A- The haze increases R. **B-** The haze reduces the distance between R and 1.

In the sky region of the clear image, the color of pixels tends to be white (approximately 255), while in the sky region of haze image the color of pixels tends to be gray. That means the haze causes decreasing the value of the atmosphere light (A) (inverse relation between amount of haze and atmosphere). For that, the distance between the atmosphere light and the pixels in the sky region will be increased, its range will be between 1 and R. The equation (6) for white pixels is:

$$\mathrm{M(x,y)}\left(1-\left(\frac{\mathrm{K}(x,y)=255}{\mathrm{A}}\right)\right)=1-\left(\frac{\mathrm{H(x,y)=255}}{\mathrm{A}}\right) \quad \textbf{(10)}$$

For the pixels in the sky region, the value of $d(x,y)$ in equation (3) approaches infinity, and $M(x,y)=0$. So,

$$\left(\frac{\mathrm{H(x,y)=255}}{\mathrm{A}}\right)\approx 1 \qquad \textbf{(11)}$$

The value of the atmosphere light (A) should be greater or equal to one, because if the light of image equal to zero that makes all values of image equal to infinity. The value of atmosphere light changes from 255 to 1 depending on the amount of haze. Therefore the ratio R_h depends on the value of atmosphere light.

The range of ratio for R_h is:$1\le\left(\frac{\mathrm{H(x,y)=255}}{\mathrm{A[1:255]}}\right)\le 255$ **(12)**

The pixels in RGB image have three channels (c). for each channel there is specific atmosphere light. The three channels have the same transmission map $M(x,y)$. Therefore, the difference in the amount of haze among the three channels depends on their atmosphere light. The haze increases the ratio and the distance, therefore in the sky and non-sky region the minimum ratio (R_h) has the minimum amount of haze. Figure (5) shows imitation of the distance of ratios (R_h) in the sky and (R_h) in non-sky region.

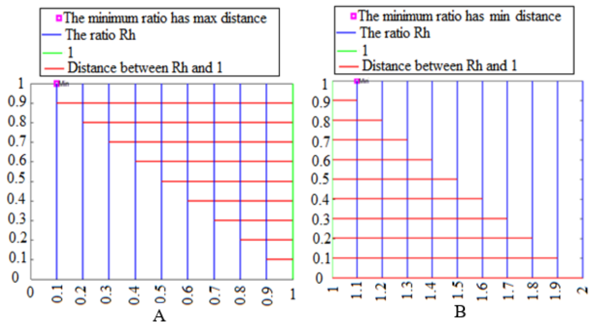

Figure 5: The minimum ratio in the haze image. **A**: The minimum ratio in the non-sky region. **B**: The minimum ratio in the sky region.

Depending on figure (5):

In non-sky region: $min\left(\frac{H^c(x,y)}{A^c}\right)\approx 0$ **(13)**

In sky region: $min\left(\frac{H^c(x,y)}{A^c}\right)\approx 1$ **(14)**

Equation (6) for the RGB image can be rewritten as:

$$\frac{H^c(x,y)}{A^c}=M(x,y)\left(\frac{K^c(x,y)}{A^c}\right)+1-M(x,y) \quad \textbf{(15)}$$

Inserting minimum operator to find the minimum ratio:

$$\min_{c\in\{R,G,B\}}\left(\frac{\mathrm{H}^c(\mathrm{x,y})}{A^c}\right)=\min_{c\in\{R,G,B\}}\left(\mathrm{M(x,y)}\left(\frac{\mathrm{K}^c(\mathrm{x,y})}{A^c}\right)+1-M(x,y)\right) \quad \textbf{(16)}$$

In sky region, $M(x,y)=0$:

$$\min_{c\in\{R,G,B\}}\left(\frac{H^c(x,y)}{A^c}\right)=1 \quad \textbf{(17)}$$

Assuming the A^c in three channel is constant.

$$A=\min_{c\in\{R,G,B\}}(H^c(x,y)) \qquad \textbf{(18)}$$

The minimum amount of haze for all pixels in haze image will be called the Low haze channel.

$$Low\ haze\ channel\ L(x,y)=A=\min_{c\in\{R,G,B\}}(H^c(x,y)) \quad \textbf{(19)}$$

Low-haze channel represents the dark channel for non-sky regions and represents the light (white) channel for sky regions, the result shows in figure 6.

Figure (6): Computing the Low-haze channel. **A**: The smooth image. **B**: Low haze channel.

3. Determining the value of white color in sky region (W^c): The highest pixel in the sky region of the low haze channel closes to the atmosphere light. The highest pixel represents the value of white color in sky region for haze image. At this step we do the following:

A) Dividing the haze image to non-overlap blocks with size 30*30.

B) Sorting the pixels of low haze channel in descending order then selecting 1% from the top order pixels with their locations in blocks.

C) Determining the value of white color in sky region: Almost the pixels in the sky regions have the same or (close) intensity values, this will lead to low value for standard deviation. While in the non-sky regions the standard deviation tends to be high due to highly variation in intensity values. Therefore, using standard deviation to differentiate between the values of the white color in sky region from the value of white objects in the non-sky region. This step determines the value of white color in sky region as the following:

First: convert color image to gray image by replacing each pixel with the average value of its three channels ((R+G+B)/3).

Second: Compute the standard deviation for each selected blocks in haze image.

Third: Select the candidate block which has the minimum value of standard deviation.

Fourth: The location of the maximum pixel in candidate block (for highest 1% pixels in low haze channel) is the location of the value of white color in sky region for haze image.

4. Computing the values of first and second atmosphere light, then choosing the maximum one between them.

The value of white color in the sky region (W^c) useful to estimate the amount of haze by finding the difference between the white color in clear image and white color in haze image. (W^c) is an indicator for the amount of haze. The atmosphere light and the white color in clear image have the same value because in clear image the white color and the atmosphere light generally have the high value (approximately [255 255 255]). So, the clear image has a correct atmosphere light:

$$A_f^c = [\,255\ 255\ 255].$$

The amount of haze can be estimated by computing the distance between the atmosphere light and the value of white color in sky region (W^c). By using equation (5)

$$D = \left(A_f^c - W^c(x,y)\right) \qquad \textbf{(20)}$$

The minimum distance between the atmosphere light and the pixel means this pixel close to the atmosphere light. $D = min\left(A_f^c - W^c(x,y)\right)$ **(21)**

The first atmosphere light for haze image can be computed directly as the following:

$$A_1^c = W^c - D \qquad \textbf{(22)}$$

The atmosphere light will be adjusted by using adjustment coefficient(δ) to recover the side effect of converting the color near the sky region to the white color when applying the equation (22).

❖ Computing the adjustment coefficient($\boldsymbol{\delta}$):

Step 1: computes the values for:
A)**SRGB**: The standard deviation for the haze image.

B) **SV**: Converting the haze image to HSV color space and computing the standard deviation for the $\boldsymbol{V}$channel.

C) **MST**: Computing the multiplying standard deviation:$MST = SRGB * SV$**(23)**

D) **AW**: The average value (AW) of the white color in sky region (W^c): $AW = sum(W^c)/3$ **(24)**

Step 2: Taking all values obtained in step1 as input to the procedure which is explained by the flowchart in figure (7) to find the adjustment coefficient(δ).

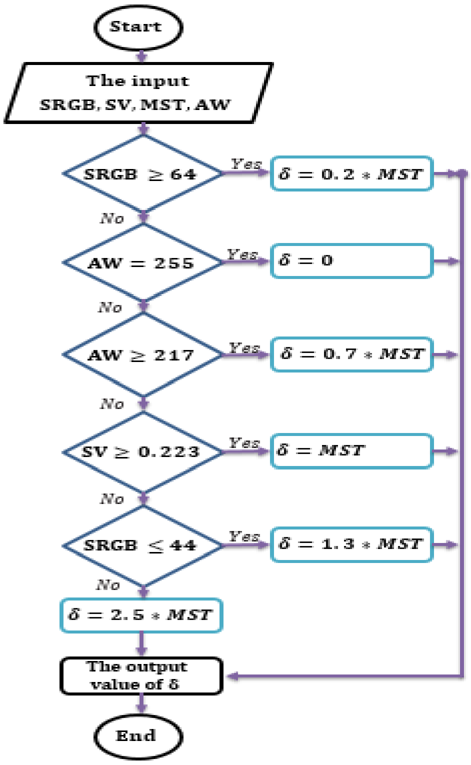

Figure 7: Flowchart for computing the adjustment coefficient (δ)

Adjustment coefficient (δ) helps to compute the second atmosphere light. $A_2^c = W^c - \delta$ **(25)**

The accurate atmosphere light is:

$$A^c = max(A_1^c,\ A_2^c) \qquad \textbf{(26)}$$

Where $A^c is$ the accurate atmosphere light.

5. Computing the values of transmission map

The transmission map $M(x,y)$is the medium which enables reflection ray to pass through it to a camera.

There are three cases for $\boldsymbol{M(x,y)}$:

Case 1: $M(x,y)$=0, the image completely haze.

Case 2: $M(x,y)$=1, the image completely clear.

Case 3: $M(x,y)$= unknown.

The unknown $M(x,y)$ computed by using the equation (16). For one pixel in three channels, $M(x,y)$ is constant. So, equation (16) can be rewrite as:

$$\min_{c\in\{R,G,B\}}\left(\frac{H^c(x,y)}{A^c}\right) = M(x,y)\min_{c\in\{R,G,B\}}\left(\frac{K^c(x,y)}{A^c}\right) + 1 - M(x,y) \quad \textbf{(27)}$$

Where in equation (27):

A) (A^c) in clear image is very high and the clear image has many low pixels because the shadow or the black objects. So the amount of $\min_{c\in\{R,G,B\}}\left(\frac{K^c(x,y)}{A^c}\right)$ is very low.

B) $M(x,y)$=1 in clear image, the equation (27) will be as: $\min_{c\in\{R,G,B\}}\left(\frac{H^c(x,y)}{A^c}\right) = \min_{c\in\{R,G,B\}}\left(\frac{K^c(x,y)}{A^c}\right)$**(28)**

While in non-sky region $min\left(\frac{H^c(x,y)}{A^c}\right) \approx 0$ as in equation (13), therefore, $min\left(\frac{K(x,y)}{A^c}\right) \approx 0$ **(29)**

C) Existence of haze means the value of $M(x,y)$ is low. When multiplying low value of ($M(x,y)$) by the low value of $\min_{c\in\{R,G,B\}}\left(\frac{K^c(x,y)}{A^c}\right)$ we get very low value.

Depending on the (A, B and C):

$$M(x,y)\min_{c\in\{R,G,B\}}\left(\frac{K^c(x,y)}{A^c}\right) \approx 0 \quad \textbf{(30)}$$

Therefore the unknown $M(x,y)$ is:

$$M(x,y) = 1 - \min_{c\in\{R,G,B\}}\left(\frac{H^c(x,y)}{A^c}\right) \quad \textbf{(31)}$$

$M(x,y)$ according to the equation (31) in the non-sky region has the low value which mean there is no distance between the scene and camera. Therefore, the image will be unpleasant. To make the image a pleasant image returning a little amount of haze to image by adding the factor C=0.85 (determined by experiments) to equation (31).

$$M(x,y) = 1 - \left(C * \min_{c\in\{R,G,B\}}\left(\frac{H^c(x,y)}{A^c}\right)\right) \quad \textbf{(32)}$$

The input in this step is the smoothing image, and the accurate atmosphere light (A^c),the result shows in figure (8).

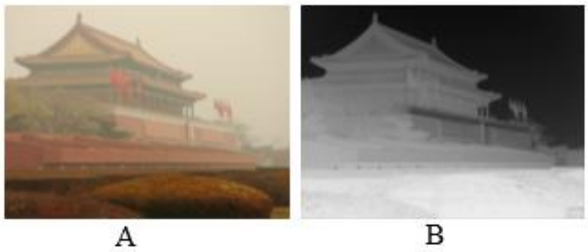

Figure (8): Computing the values of transmission map. **A:** Smooth image. **B**: Transmission map.

6. Recovering the de-haze image

The de-hazed images are recovered by using the model as the following:

$$K^c(x,y) = \frac{H^c(x,y) - A^c}{\max(M(x,y),F)} + A^c \quad \textbf{(33)}$$

Where $K^c(x,y)$ is the recovered image, $H^c(x,y)$ is the input haze image, $M(x,y)$ is the transmission map, A^c is the accurate atmosphere light, while (F=0.001) is the restoration factor used to avoid zero value on the dominator. Figure (9)shows the result of this step.

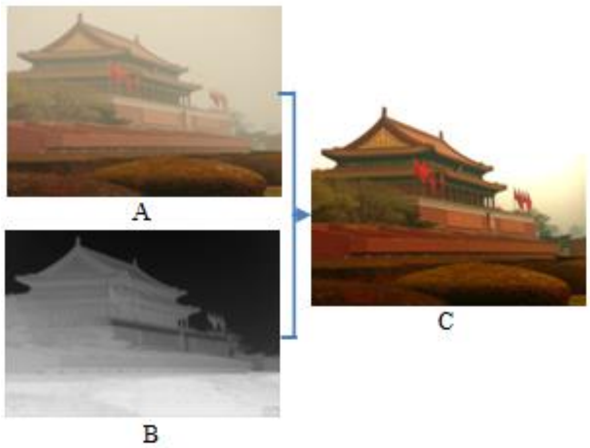

Figure 9: Recovering the de-hazed image. **A**: Input haze image. **B**: Transmission map. **C**: The recovering image.

7. Improving the local contrast

Contrast enhanced to sharping the RGB image by using Unsharp filter. The sharping RGB image will convert to HSV color model, and from this model we select the V channel. The (V) channel improved by using equation (34):

$$new\ (V) = 0.04 + 1.4 * Log\left(1 - old(V)\right) \quad \textbf{(34)}$$

The new image (V) use with (H and S channels) to reconstruct RGB image. Figure (10) shows the result.

Figure 10: Improving the local contrast. **A**: The recovering image. **B**: The de-haze image.

QUALITY CRITERIA

Generally, there are three kind of quality measurement depending on the information availability of reference image: full Reference quality, Reduced Reference quality and No reference or blind quality [6]. At this paper we used two kinds of quality criteria:

First: Full reference quality criteria

These quality criteria used when all information about the original image is available. We will use PSNR (peak signal to noise ratio), RMSE (root mean square error), SSIM (structural similarity index) and UIQ (the universal image quality index) [7][8].

Second: No reference or blind quality criteria

These kind quality criteria used when information about the original image is unavailable. Most methods work on the removal haze depending on the blind quality criteria (e-descriptor, σ- descriptor, r- descriptor) which are suggested by Hautire[9], in addition to the Contrast to Noise Ratio (CNR) [10].

Where (e-descriptor): counts the number of visible edge in the de-haze image compared with haze image.

(r-describer): counts the ratio of the visible edge in haze image to de-haze image.

(σ- descriptor): counts the number of pixels that completely dark or white after applying de-hazing.

THE PERFORMANCE OF THE PROPOSED METHOD

The proposed method tested by using more than 3000 images (real and synthetic). (1) 1200 Real images chosen randomly from the internet. (2) 1815 synthetic images taken from FRIDA Database [11], FRIDA2 database[12] and HAZY A DATASET [13].

Measuring the performance of de-haze image included:

1. Comparing visible results for different methods

In this test we remove haze from image in figure 11(A) by using many methods. Figure 11 compare visually the results. It is clear the proposed method gives better image than other methods.

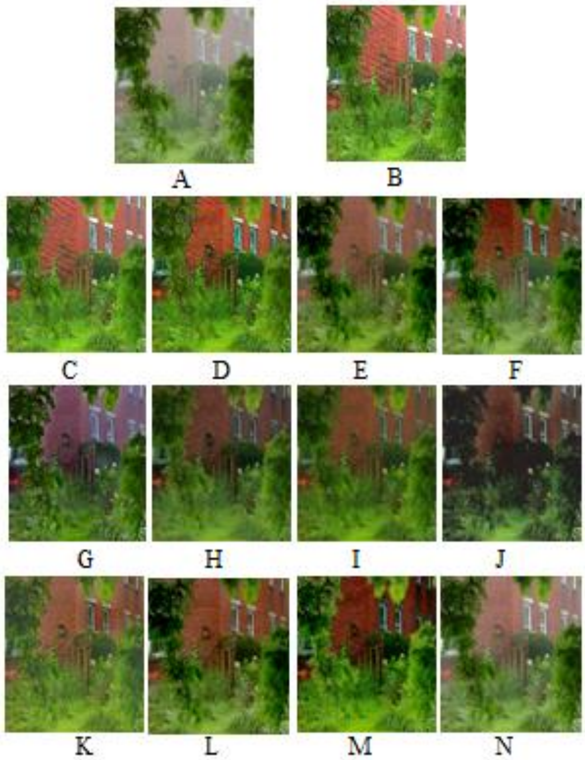

Figure 11: Comparing the result of the proposed method with other methods visually. **A:** Haze image. **B**: De-haze image by the proposed method. **C**: De-haze image by Nidhal [15]. **D**:De-haze image by Gibson [16]. **E:** De-haze image by K. He [2]. **F**: De-haze image by Fattal_1 [17]. **G**: De-haze image byAncuti [18]. **H** : De-haze image by Zhu [19]. **I**: De-haze image by Liang [20]. **J:** De-haze image byZhenfei [4]. **K**: De-haze Image by Berman [21]. **L**: De-haze image by Fattal [3]. **M**: De-haze image by Tarel [22]. **N:** De-haze image by Tang [23].

2. Comparing blind quality criteria for different methods.

At this test we measure some of blind quality criteria (e-descriptor, $\sigma -$ descriptor, r- descriptor and CNR) for the de-hazed images result from using proposed method and many other methods. Comparing between the values of these criteria shows in the table 1. The best result for (e, r and CNR) is the maximum value and the best result for (σ) is the minimum value.

Table 1: Results of tests with blind quality criteria (e, σ, r and CNR) for de-hazing image by different methods.

Methods	**e**	σ	**r**	**CNR**

	Best /Max	Best /Min	Best/ Max	Best/Max
De-haze by Tang	**0.097001**	**0**	**1.880089**	**77.928301**
De-haze by Tarel	**0.087633**	**0.258081**	**1.969243**	**89.537481**
De-haze by Fattal	**0.079988**	**2.538384**	**2.01237**	**81.005373**
De-haze by Berman	**0.119669**	**0.011111**	**1.640621**	**82.786684**
De-haze by Zhenfei	**-0.092432**	**0**	**1.158967**	**54.416685**
De-haze by Liang	**0.13200**	**0.008081**	**1.573066**	**71.045396**
De-haze by Zhu	**0.124203**	**0.000515**	**1.164786**	**54.590007**
De-haze by Ancuti	**0.086680**	**0.050505**	**2.05108**	**74.907195**
De-haze by Fattal_1	**0.104392**	**3.647475**	**1.653182**	**85.901602**
De-haze by K., He	**0.077155**	**2.815657**	**1.321442**	**74.062826**
De-haze by Gibson	**0.040187**	**0.737879**	**2.350912**	**108.887862**
De-haze by Nidhal	**0.114219**	**0**	**3.802941**	**143.3012**
De-haze by proposed method	**0.17324**	**0**	**4.453215**	**155.304075**

From table 1 we conclude that the proposed method has best results comparing with other methods.

3. Visibility Test for Synthesis Image

De-hazing the synthesis haze image by proposed method and other methods, the results compared visually with the original image (ground truth image) figure 12A.

4. Synthesis images in figure 12 tested by measuring the reference and blind criteria. The results of proposed method compared with other methods and shows in table 2. The best result for (PSNR, SSIM, UIQ, e, r, CNR) is the maximum value and the best result for (RMSE and σ) is the minimum value.

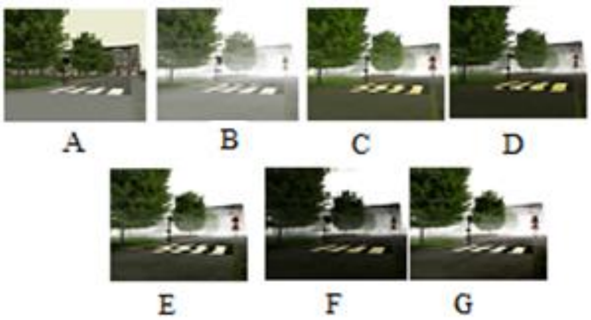

Figure 12: Comparing the result of the proposed method with other methods, for de-hazing image. **A**: Ground truth Image. **B**: Heterogeneous _Haze Image. **C**: De-haze image by the proposed method. **D**: De-haze image by Liang [20]. **E**: De-haze image by K., He [2]. **F**: De-haze image by Tan [5]. **G**: De-haze image by Fattal_1 [17].

Table 2: Comparing values of quality criteria (PSN, SSIM, RMSE and UQI) and blind quality criteria (e, σ, r and CNR) for de-hazing using proposed method and many other different methods.

Methods	**Reference quality**				**Blind quality**			
	PSNR	**SSIM**	**RMSE**	**UQI**	**e**	***σ***	**r**	**CNR**
De-haze by Fattal_1	**10.914**	**0.542**	**72.581**	**0.534**	**0.672**	**0.253**	**1.672**	**42.987**
De-haze by Tan	**11.859**	**0.423**	**65.125**	**0.393**	**0.672**	**0.075**	**1.049**	**32.635**

De-haze by He	**12.054**	**0.592**	**63.66**	**0.561**	**0.649**	**0.067**	**1.639**	**43.676**
De-haze by Li	**12.641**	**0.581**	**59.498**	**0.568**	**0.939**	**0.147**	**1.865**	**49.049**
De-haze by proposed method	**13.131**	**0.66**	**56.231**	**0.741**	**0.94**	**0**	**1.97**	**52.039**

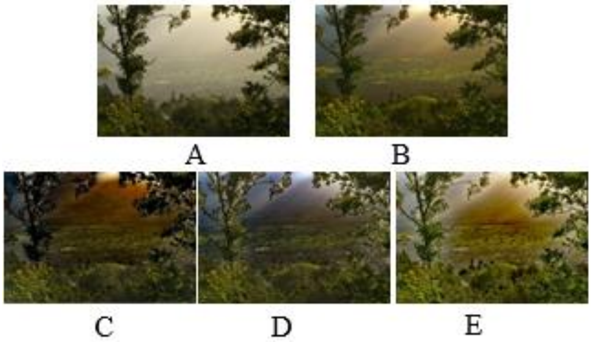

Figure 13: Comparing the result of the proposed method with other methods for de-hazing image when the light in opposite direction of camera. **A**: Haze image. **B**: De-haze image by proposed method. **C**: De-haze image by Fattal [3]. **D**: De-haze image by Santra [14]. **E**: De-haze image by K., He [2].

Table 3: Comparing the running time (Measured in seconds) for de-hazing image by several methods.

Methods	**Size of images**					
	845*496	**768*497**	**629*420**	**400*600**	**512*460**	**512*384**
He[2]	**207.00**	**189.80**	**171.45**	**122.20**	**119.76**	**99.30**
Tarel [22]	**19.02**	**15.12**	**7.44**	**6.66**	**5.13**	**4.72**
Zhu [19]	**3.30**	**3.10**	**2.47**	**2.44**	**2.72**	**2.21**
Ju[24]	**7.20**	**6.70**	**4.20**	**4.57**	**4.30**	**4.20**
Meng[25]	**5.37**	**4.85**	**4.03**	**3.12**	**3.25**	**2.90**
Zhenfei[4]	**4.85**	**3.63**	**2.14**	**1.90**	**1.75**	**1.60**
Nidhal[15]	**1.70**	**1.60**	**1.50**	**1.40**	**1.30**	**1.20**
proposed method	**1.50**	**1.40**	**1.20**	**1.16**	**1.15**	**1.10**

5. Solving hallo problem

One of haze removing problems is the hallo. When the camera close to the sense, and the light in opposite direction of camera (behind sense or object), at this case most of the current methods remove the haze but leave hallo around the edges. While the proposed method remove haze without leaving any traces of hallo. Figure 13A shows image with light behind the objects, the other figures (13B … 13E) shows the results of removing haze from image in figure 11A by proposed method and other methods.

6. Running Time

Running time measured for proposed method and other methods. The results compare with running time for other methods when using the same haze image. Proposed method gives better result than other methods as shown in table 3.

CONCLUSIONS

In this paper, we suggested a new method for haze removal. In this method we used small size window for the filter (which is used for removing noise) to preserve the edge and detail of the image. In this paper we suggested a new formula to compute the atmosphere light directly, and solve the problem of converting some non-haze pixels of image to white color, for that we compute two values for atmosphere light with two different methods, then choose the maximum one between them. One of the paper contribution is using the standard deviation to determine the sky region. Running time is reasonable time. Also we suggested a new formula to enhance the local contrast of the image.

The proposed method is more efficient compared with other methods. For future works, using the features of the image to solve the problem of haze such as; Entropy, energy, contrast and correlation.

SAMPLES FOR DE-HAZE IMAGES

Figure (14) show samples for haze removal by using the proposed method.

Figure 14: Samples for haze removal by using the proposed method.

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