ISSN: 2321-8169
6802 - 6807

A Novel Algorithm for Dehazing an Image

Archana Kaushik
Computer Science and Engineering Dept,
MVN University
Faridabad ,India
Email : archanakaushik297@gmail.com

Alka Choudhary
Computer Science and Engineering Dept.
MVN University
Faridabad, India
Email : alka.chaudhary@mvn.edu.in

Abstract - Image dehazing plays a vital role in the field of image processing. Previously, many researchers have suggested many techniques like histogram equalization and gamma transformation in order to achieve the target. But these techniques have many limitations like different degree of polarization, different kind of weather conditions or depth information of pixel in image. The proposed work has tried to develop a more effective and reliable image quality assessment method that can evaluate the quality of the proposed dehazing algorithms. It proposed a robust method that is capable enough to improve the detection quality of hazed image by minimizing atmospheric haze effect by using local min operator to reduce time complexity. As compared to previous work it provides better results.

Keywords*- dehazing, histogram equalization, gamma transformation, degree of polarization.*

*****

I. INTRODUCTION

In literature, various articles have been suggested for haze removal from images. Existing literature also addresses the issue of noise that has relied on multiple images either for denoising prior to dehazing or in the dehazing processes itself. It is difficult to find a sequence of images or multiple images at the same time [1, 2, 3]. So, single image based approaches are one of the most successful with the consideration of the "dark channel prior" [4]. According to our perception and literature survey, almost all images contain some amount of noise due to some hardware issue like sensor error. Considering this fact, the noise must be included in the image model for haze formation [1, 2]:

$$Y(x) = I(x) + n(x) = R(x).\ t(x) + a\ (1 - t(x)) + n(x) \quad (1)$$

Here, Y is the observed image, and noise contribution is n which is assumed to be independent and identically distributed (I.I.D.) throughout the image, with zero mean and variance. Assuming that the atmospheric light and transmission map are perfectly known, if the scene radiance is recovered by a naive inversion and the noise contribution is amplified by 1/t(x).

Most of the outdoor vision based applications such as outdoor video-surveillance as well as monitoring and analysis of traffic systems. For these applications, improving the dehazing technique is highly desired for real-time based systems. On the one hand, removal of haze from image can increase the visibility in order to restore the real color of the scenery objects. On the other hand, developing or recovering the haze-free image one can benefit for vision algorithms [1, 3, 4,] (for instance, image annotation, image segmentation and so on). For these reasons, in the area of image processing and computer vision, image dehazing has important and realistic significance.

Till now, many methods have been proposed to remove haze from the outdoor images. Previously, many researchers have suggested many techniques like histogram equalization and gamma transformation in order to achieve the target. But these techniques have many limitations like different degree of polarization, different kind of weather conditions or depth information of pixel in image [3, 4, 5].

These methods can hardly be used for real-time applications because of these limitations. One of

Figure 1.1: (a) Input image (Hazed image) and (b) Resulting image (Dehazed image)

the main problems is that these methods are not as much convenient to obtain additional information for removal of the haze from image. In this context, the main attention should be given to develop a dehazing algorithm for single image. Here, we have presented a simple example for real hazy image and Dehazed image as shown in *Figure 1.1*. In some case, denoising prior to dehazing is also required and the proposed approach can be suitable enough to suppress the noise automatically in dehazed image. However, the proposed method is more appropriate to preserve maximum information.

A. *Problem Statement*

One of the key problems observed by us in image dehazing is that it is very challenging to recognize the white scenery objects whose pixel value is inherently similar to atmospheric light's value. According to literature survey and various methods proposed by various researchers, the state-of-the-art algorithms are suitable to acquire impressive dehazing effect in most cases. However, these algorithms have the common limitation that may be the big obstacle to progress in the area. In this chapter, we propose the following issues which are the significant challenges of single image dehazing. In literature, there is requirement of a more robust method for image dehazing in inhomogeneous atmosphere. Here, this work has tried to develop a more effective and reliable image quality assessment method that can evaluate the quality of the proposed dehazing algorithms.

It is to be noted here, the main contribution of the proposed work has been listing as:

- To develop a method that could reduce the hazed part of image.
- To improve the detection quality of hazed image by minimizing haze part.
- To focus on dehazing caused of environmental sources like haze, fog, dust, mist *etc*. The image is deblurred while a user is capturing an image from his/her digital camera and due to above mentioned external sources available in the environment.

The removal of haze can produce depth information that is a benefit for many vision algorithms and advanced image editing based applications. The haze removal is a challenging [1, 3, 5] and problematic issue because the haze is dependent on unknown depth information of the pixel in an image. Generally, images captured in outdoor scenes often degrade due to haze problem, resulting in contrast reduction or color fading. For many reasons, it is required to remove these effects. Unfortunately, removal of haze is difficult due the inherent ambiguity between the haze and the underlying scene. The haze removal is used mainly for enhancing image quality in image analysis. *The haze is simply a set of atmospheric effect which reduces contrast the in an image.*

Therefore, the proposed method is also more suitable when it comes to an offline system.

II. THE PROPOSED ALGORITHM

A. *Brief description of working algorithm*

The complete haze removal procedure is summarized in above algorithm. In the beginning, the proposed work read a single hazed image from the dataset. After reading the image we have converted it into a simple 1-dimentional vector for less computation. Since the dark channel basically relies on sample minima because dark channels are sensitive to the outliers. The artifacts arise during computation of the dark channel. As mentioned in (algorithm 1.1), the dark channel calculation focused on minima of pixel intensity that simply selects minimum value of intensity for each pixel in the local patch. In literature, lots of methods are available that robustly estimate the dark channel from dehazed image. With the help of extension of dark channel, we have computed the transmission map that also assumes the presence of noise. This is more sophisticated approach that has taken by applying stochastic approximation to locate the local minima which is followed by the point estimate. The point estimate is needed (for example, to estimate the atmospheric light), this method simply denoise the entire image by removing noise automatically with the assumption as a pre-processing step. Now, simply compute the transmission map from dark channels, by selecting minima of normalized dark channels. Finally recover the scene radiance from most haze-opaque based minima and subtracting from 1 as shown in algorithm 1.1. In computer vision and computer graphics, the model widely used to describe the formation of a haze image is as follows [6, 8, 9]:

$$I(x) = R(x).\ t(x) + L(1 - t(x)) \qquad (2)$$

Where I, R and L are the observed intensity, scene radiance and global atmospheric light respectively. Whereas t is the medium transmission which describes the portion of un-scattered light that reaches the camera. The goal is to recover R, L and t from I. The first term on the right hand side of the equation (2) is i.e. R(x).t(x) is called direct attenuation [8] which is used to describe scene radiance and its decay in medium. And the second term L(1-t(x)) is called air-light [6, 16] which is the result of previously scattered light and contributes to shift in scene color. In case of homogenous atmosphere, t is defined as:

$$t(x) = \exp(-\beta d(x)) \qquad (3)$$

Where scattering coefficient of atmosphere β is attenuated exponentially with the scene depth d. Geometrically, In RGB color space, vectors L, I(x) and R(x) are coplanar and their end points are collinear. The transmission *i.e.* t(x) is the ratio of two line segments:

$$t(x) = \frac{\|L - I(x)\|}{\|L - R(x)\|} = \frac{L^c - I^c(x)}{L^c - R^c(x)}$$

(4)

Where c ∈ {r, g, b} is color channel index. Based on this model, Tan's method [8] focuses on enhancing the visibility of the image. For a patch with uniform transmission t, the visibility (sum of gradient) of the input image is reduced by the haze, since t<1:

$$\sum_x \|\nabla I(x)\| = t \sum_x \|\nabla R(x)\| < \sum_x \|\nabla R(x)\|$$

(5)

Here, the transmission t in simply a local patch that has estimated by maximizing the visibility of the patch. It also satisfies a constraint that the intensity of R(x) is less than the intensity of L.

B. Low Intensity Pixel Selection

In case of most of the non-sky objects, at least one color channel has the lowest intensity at some pixels. In other words minimum intensity value is very low in such a patch. Formally, for an

Image R, we define:

$$R^{dark}(x) = \min_{c\in(r,g,b)} \left(\min_{y\in\Omega(x)} (R^c(y)) \right)$$

(6)

Where R^c is a color channel of R and Ω(x) a local patch centered at x. Except for the sky region the intensity of R^{dark} is very low and tends to be zero.

C. Haze Removal Model

Our final equation for transmission yields the following form, where ω is a constant parameter to introduce some hazes for distant objects which is application based.

$$\tilde{t}(x) = 1 - \omega \min_{c} \left(\min_{y\in\Omega(x)} \left(\frac{I^c(y)}{L^c} \right) \right)$$

(7)

This modification adaptively and keep more haze for the distant objects. The value of ω is fix to 0.95 for all results reported in this work. In proposed experiments, this method uses the local min operator using Marcel van Herk's method [9] whose complexity is linear to image size.

D. Recovering the Scene radiance

With the transmission map, this work simply recovers the scene radiance according to the equation:

$$R(x) = \frac{I(x) - L}{\max(t(x), t_0)} + L$$

(8)

Where t_0 has typical value of 0.1.

E. Estimating the Atmospheric light

The atmospheric light i.e. *L* is generally estimated from the most haze-opaque pixel i.e. pixel with high intensity is used to represent atmospheric light. But this assumption becomes invalid in case of bright objects such as white car or a white building. In previous section we discussed that the low intensity pixel is used to approximate the haze denseness well. We can also use it to improve the atmospheric light estimation. For that we choose 0.1% of the brightest pixels in low intensity region which are most haze-opaque pixels. Among these pixels the pixel with highest intensity is selected as atmospheric light which yields the robust result for estimation of atmospheric light.

The proposed method for haze removal procedure is summarized in algorithm 1.1:

Algorithm 1.1:

Step 1: Read the image, I from dataset

(i) Convert image into 1- D array, I(:);

Steps 2: Estimate the atmospheric pixels i.e. estimate top 0.1 % bright pixels in dark channel because these pixels belong to haze-opaque.

(i) Call dark_Channel(image, patch size).

(ii) Find minimum across all Channels.

Step 3: Find the highest intensity pixel from the original image using the 1-D vector calculated above.

(i) If intensity > sum(highest intensity
) then

highest_Intensity = pixel Intensity

(ii) Now set this intensity as atmospheric lighting pixel.

L(:, :, dim) = L(:, :, a) + highest Intensity(:, :, a);

(iii) Resize A into 2-D image.

L (:, :) = L (:, :) + highest Intensity(:, :) ;

Step 4: To estimate the transmission

$t'(x,y) = 1 - \min_c (\min_{y\in\pi(x)}(I_c(y)/L^c))$;

(i) Transmission

$t'(x,y) = 1 - w.\min_c (\min_{y\in\pi(x)} (I_c(y)/L^c))$;

// Dark Channel of normalized haze image.
// It directly provide the estimation of transmission.

// **for sky region:**
Evaluate $\min_c (\min_{y\in\pi(x)} (I_c(y)/ L^c))$; when t(x) = 0;

// **for non sky-region:**
Evaluate $\min_c (\min_{y\in\pi(x)} (I_c(y)/ L^c))$; when t(x) = 1;

Step 5: Recovering the scene Radiance:
R(x) = I(x) - L / max (t(x, y), t0) + L;
// L: estimate from most haze-opaque and R represent the //
radiance based resulting image

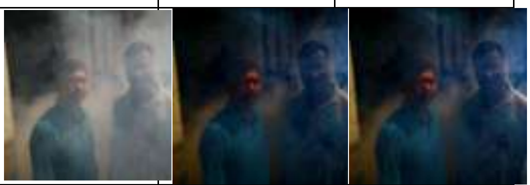
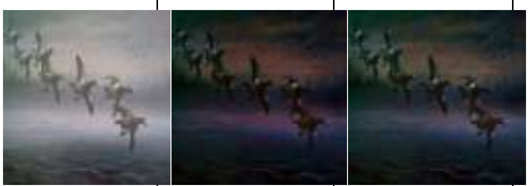
Step 6: Dehazed the image and write the image.

III. EXPERIMENTAL SETUP AND PERFORMANCE ANALYSIS

In the experimental setup section, we have presented experimental results and analysis. Here, all the experiments have processed over colored images. In this experimental section, the proposed method has been implemented in MATLAB-2011 (b) and run all experiments on a windows 8.1 (64-bit) operating system having hardware configuration of 1.73 GHz Core i7 CPU and 8 GB RAM. The images are taken from different-2 sources and dataset. All images are having different sizes. In this chapter presents some examples that clearly show the performance of proposed method.

This method has been employed in this chapter for removal of haze from input hazed image. The performance of the above algorithm has clearly depicts the importance and applicability of this method in real-time application. This work presents proposed work with patch size 3x3 and 5x5.

Table 1.1: Visual Analysis for Dehazed Images

Image Name & Size	**Input Image**	**Result-1**	**Result-2**
Trees.jpg (1076x723)			
tiananmen 1.jpg (600x450)			
fishers.jpg (512x346)			
foggy_bench.jpg (800x600)			
D.jpg (960x720)			
morning_bills.jpg (600x393)			
Haze.jpg (400x300)			
Wolf.jpg (640x382)			

The peak-signal-to-noise ratio (PSNR) is used for perception of quality of an image. It is to be noted that *higher value of PSNR indicates the higher quality of image*. Generally, PSNR (in dB) can be defined as:

$$PSNR = 10 \cdot \log_{10}(MAX_I^2/MSE) \quad (9)$$
$$= 20 \cdot \log_{10}(MAX_I/)$$
$$= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE)$$

Where, MAX_I is the maximum possible pixel value of the image. When the pixels are represented using 8 bits per sample, this is 255. One more important point is to remember, in case of absence of noise, suppose we have two images *I* and *K*, both images are identical, then the MSE is zero and in such case the PSNR is infinite. For color images with three RGB values per pixel, the definition of PSNR is the same except the MSE is the sum over all squared value differences divided by image size and by three. Alternately, for color images the image is converted to a different color space and PSNR is reported against each channel of that color space.

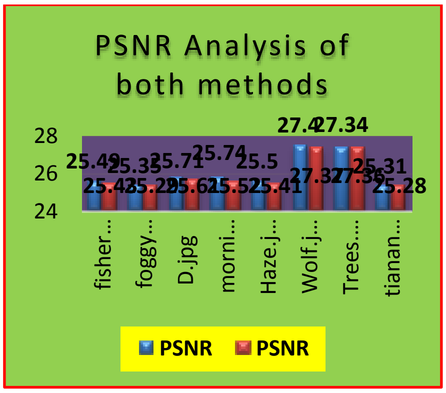
In this work, the value of PSNR has been depicted in Table 1.2 that clearly shows the performance of proposed work at different – different patches i.e. 3x3 and 5x5. In the table 1.2, first column represents input image, second column consist of Result-1 by proposed method at patch size 3x3, and third column represents Result-2 of proposed method computed with patch 5x5.

Table 1.2: PSNR based performance analysis for dehazed Images

Image Name	**PSNR** (Result-1)	**PSNR** (Result-2)
fishers.jpg	25.49	25.43
foggy_bench.jpg	25.35	25.29
D.jpg	25.71	25.61
morning.jpg	25.74	25.52
Haze.jpg	25.50	25.41
Wolf.jpg	27.40	27.37
Trees.jpg	27.34	27.36
tiananmen1.jpg	25.31	25.28

The analysis of above PSNR-values computes from both methods has shown in the figure 1.2. In this figure horizontal row shows the input images and vertical bar shows the value of PSNR. It clearly shows the effective performance achieved from result-1 of proposed-1 method.

Figure 1.2.Peak-Signal-to-Noise Ratio based Performance Analysis



From the above results, we have seen the overall performance of proposed method at various patches. The MSE based error analysis has shown in figure 1.3. The mean-square error can be computed in table 1.3 as given below:

Figure 1.3. Mean Square Error Analysis

The run time performance has shown in Table 1.4. According to the run time analysis, the proposed method performs much better at patch 5x5. With the patch 5x5, proposed method's implementation has taken minimum run-time.

Table 1.3: MSE based performance analysis

Image Name	**MSE** (Result-1)	**MSE** (Result-2)
fishers.jpg	185.16	187.66
foggy_bench.jpg	191.34	193.87
D.jpg	176.01	180
morning.jpg	174.94	183.82
Haze.jpg	184.89	188.68
Wolf.jpg	119.39	120.2
Trees.jpg	120.92	120.23
tiananmen1.jpg	192.94	194.13

Table 1.4: Time based performance measure

Image Name	**Time** (in Seconds; Result-1)	**Time** (in Seconds; Result-2)
fishers.jpg	22.590830	21.865047
foggy_bench.jpg	61.957985	58.878102
D.jpg	70.576659	65.866725
morning.jpg	32.833963	32.385799
Haze.jpg	16.769780	15.925882
Wolf.jpg	32.894274	31.585261
Trees.jpg	55.429127	52.998578
tiananmen1.jpg	38.633134	36.238943

A. *Advantages and Limitation*

This method has some advantages and limitations, these are described as:

- The main advantage of proposed work is that this method automatically detects the dehazed image.
- This method improves the detection quality of image in critical situation when normal real-time based camera or image / video capturing device are not able to work properly.
- The use of local min operator make the proposed method faster at execution time, hence improved the run-time complexity.
- This work can be applicable to real-time based applications like GIS, satellite imaging, thermal imaging. This work can also applicable in various other computer vision based surveillance applications like indoor-outdoor surveillance, driver assistance system, transportation system, traffic surveillance, coastal/sea/port/air surveillance, border surveillance system *etc.*

The proposed work has some limitations as given below:

- The proposed method not solves the sun's influence on the sky region and the blueish hue near the horizon very well.
- The main limitation is that we need only one patch size and input image at the time of initial state i.e. during running stage. Apart from these external parameters, it also incorporates better detection quality of image.

B. *Observation and discussion*

In this section, we have summarized experimental results and analysis. These are described briefly as given below:

- The table 1.1 presents visual description of input image and output image. The proposed results depicts better performance in Result-1 column.

- Table 1.2 clearly shows the peak-signal-to-noise ration based analysis. We know that the *higher value of PSNR indicates the higher quality of image*. Therefore, Result-1 in table 1.2 at patch size 3x3 has been considered as better method as compare to second i.e. Result-2.
- The MSE measure the mean square error as shown in table 1.3. In maximum cases, the Result-1 based method represent minimum error and hence better method for image analysis.
- According to table 1.4, the Result-2 based method take minimum execution time but with this time the quality of proposed method is not good as compare to proposed method at patch size 3x3 *i.e.* as shown in table 1.4.
- The overall performance is clearly analyzed from figure 1.1, and figure 1.2.

The main motive of proposed work is to find better quality, so we focus on the quality of image. There is minimum difference between time based analyses between both methods. Based on overall results and analysis shown in Table 1.1, 1.2, 1.3, 1.3 and figure 1.2 and figure 1.3, this work has consider proposed method at patch size 3x3 (proposed-1) as compare to other method.

IV. CONCLUSION AND FUTURE DIRECTIONS

The haze removal is used mainly for enhancing image quality of an image in image analysis. The haze is simply a set of atmospheric effect which reduces contrast the in an image. In literature, main problems observed in image dehazing is to recognize the white scenery objects whose pixel value is inherently similar to atmospheric light's value. So, there is requirement of a more robust method for image dehazing ininhomogeneous atmosphere. This work proposed a simple, efficient and powerful method haze removal in image. This work proposed a robust method that is capable enough to improve the detection quality of hazed image by minimizing atmospheric haze effect.The local min operator used because its complexity is linear to image size and make proposed method faster.The proposed method also reduced dehazing effect in image caused of environmental sources like haze, fog, dust, mist *etc.*In the experimental results, the proposed results are better than the source image as shown in table-1.1. The detection quality of proposed-1 method at patch size 3x3 is much better as compare to proposed-2 method. Due to large mask size, proposed-2 method executes faster than proposed-1 method, but its detection quality degrades as compare to proposed-2. The large value of PSNR and less MSE have shown the quality based detection evaluated from proposed-1 method. On the basis of overall analysis of figure 1.2 and 1.3, the overall performance of proposed-1 method is better as compare to second method.

In the further extension of this work, we will apply this work in video data that can be applicable for real-time based computer vision applications like traffic vehicles to reduce the haze part for driver surveillance system, army, police patrolling, air surveillance, other indoor-outdoor surveillance system.

REFERENCES

[1] Won-Tae Kim, Hyun-Woo Bae, and Tae-Hwan Kim, "Fast and Efficient Haze Removal", International onference on Consumer Electronics, IEEE, page 360-361, 2015.

[2] Jiaming Mai, Qingsong Zhu, Di Wu, "The Latest Challenges and Opportunities in the Current Single Image Dehazing Algorithms", International Conference on Robotics and Biomimetic, page 118-123, Dec-2014.

[3] Kaiming He1 Jian Sun2 Xiaoou Tang, "Single Image Haze Removal Using Dark Channel Prior", International Conference on CVPR, 2014.

[4] Erik Matlin and Peyman Milanfar, "Removal of Haze and Noise from a Single Image", SPIE digital library, 2012.

[5] Garima Yadav, Saurabh Maheshwari, Anjali Agrawal, "Fog Removal Techniques from Images: A Comparative Review and Future Directions", Int. Conf. on Signal Propagation and Computer Technology, IEEE, page 44-52, 2014.

[6] R. Fattal, "Single image dehazing", Int. Conference SIGGRAPH, pages 1–9, 2008.

[7] P. Chavez, "An improved dark-object substraction technique for atmospheric scattering correction of multispectral data", Journal of Remote Sensing of Environment, volume 24, page 450–479, 1988.

[8] R. Tan, "Visibility in bad weather from a single image", Int. conf. on CVPR, pages 1-8, June 2008.

[9] M. van Herk,"A fast algorithm for local minimum and maximum filters on rectangular and octagonal kernels", Pattern Recognition Letters, volume 13, page 517–521, 1992.