A Comparative Study- Dehazing Method Based on Homomorphic Filtering and Linear Transformation

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Abstract— Images captured via camera in the bad weather conditions like hazy or foggy ones would result in degradation of images. This is mainly due to the scattering of atmospheric light. This could lead to the deterioration of the image due to the scattering of atmospheric particles and due to the presence of haze. In this paper, a comparison between two algorithms is made, one is a fast algorithm for single image dehazing is proposed using the homomorphic filtering and the other is a single image dehazing using the linear transformation. In these both techniques, firstly, to accurately measure the atmospheric light an additional channel method is proposed based on quad-tree sub-division. After finding the atmospheric light portion in the input image filtering is being applied. For both the techniques, filtering is being applied, in which homomorphic filter is used in one and in the other minimum filtering is being used and then gaussian blurring. At last the haze-free image is obtained as the result of atmospheric scattering model. Number of both subjective and objective evaluations are being done with the aid of experiments which shows that this algorithm can clearly and naturally recover the image, with at most clarity at the edges where there is sudden changes in the depth of field. Here the algorithmic time complexity is the linear function of the image size. This has advantages in the running time my maintaining balance between the running time and processing.

Keywords: Dehazing, Image Restoration, Image Enhancement, Homomorphic Filtering, Linear Transformation, Contrast Enhancement

I. INTRODUCTION

A. General

Image dehazing is very much essential for the accurate extraction of the image features that which directly influence the computer vision systems [1]. Due to the atmospheric suspended particles (aerosols, water droplets, etc.) that absorb and scatter light before reaching a camera, outdoor images that are captured in bad weather(haze, fog, etc.)[2] are significantly degraded and yield poor visibility, such as blurred scene content, reduced contrast, and faint surface color. Hence in the hazy or foggy weather the quality of the image severely degrades due to the scattering of light by the atmospheric particles. Its research results can be widely used in urban transportation[1],outdoor video surveillance [3], driver assistance systems [4], and the satellite remote sensing [1]. In addition, they provide reference values for underwater image analysis [6] and rainy and snowy image processing fields. In addition, they provide reference values for underwater image analysis [6] and rainy and snowy image processing fields. In existence there are two major categories of dehazing methods: image enhancement-based[11] method and image restoration based methods.

Image enhancement–based methods include histogram equalization [12], the Re-tinex method [13], homogeneous filtering [14], wavelet transformation [15], and others. The main purpose of this enhancement techniques is to satisfy the visual perception of human eye and provide greater convenience.

To maintain the balance between efficiency and speed, a fast image restoration based method is proposed by assuming that a linear relationship exists in the minimum channel between the hazy image and the haze free one.

B. Model Based On: Atmospheric Scattering

On the basis of atmospheric scattering theory, the scattering of atmospheric particles is mainly divided into two parts: one is due to the attenuation process of reflected light from the object surface to the camera and the other is due to the scattering of air-light reaching the camera [8]. A diagrammatic representation of the atmospheric scattering model is shown in Fig 1. The scattering model of a hazy image can be expressed as,

$$I(x) = J(x)t(x) + A(1 - t(x))$$

where x is the coordinates, I(x) is hazy image, J(x) is the haze-free image, A is the atmospheric light, and t(x) is the medium transmission map. where I is the observed intensity, J is the scene radiance, A is the global atmospheric light, and t is the medium transmission describing the portion of the light that is not scattered and reaches the camera. The goal of haze removal is to recover J, A, and t from I. The first term J(x)t(x) is called direct attenuation [6], and the second term A(1 - t(x)) is called air light. Direct attenuation describes the scene radiance. In the above equation there are double unknowns, haze-free image J(x), and the transmission-map t(x), which is severely ill-posed. However, if the depth information of an image is known or if we have some prior knowledge for the single image, then J(x) can still be resolved.

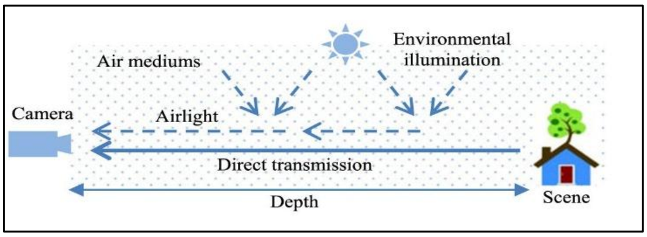

Fig. 1: Atmospheric light scattering model (Wencheng Wan et.al , 2017)

C. Dehazing Method Based On Filtering

The flow chart of the proposed method is shown in Fig. 2, which is divided into three steps according to the atmospheric scattering model.

1) Atmospheric light estimation[2] is performed through grayscale transformation to find I(x). Then, the quad-tree subdivision is adopted to obtain the sky region, R(x), and

finally, the atmospheric light A is obtained by calculating the average gray of the sky region.

2) A transmission map is estimated by calculating the minimum color channel of I(x) to obtain Ic g(x).Then, the homomorphic filtering is being applied to the grayscale image that is being obtained and hence the noise and other variations are being removed and then contrast enhancement is applied that would have increase the visual perception of the human eye.
3) Image restoration with parameters t(x) and A is used to recover the haze-free image based on the atmospheric scattering model.

II. METHODOLOGY FOR DEHAZING USING HOMOMORPHIC FILTERING AND USING LINEAR TRANSFORMATION

A. Atmospheric Light Estimation

Another key factor for the estimation in image dehazing[1] is atmospheric light. According to its own haze characteristics, a large amount haze will increase the brightness of an object in an image. In tan's work [10], the brightest pixels in a hazy image are used as the atmospheric light. Additionally, He et al. [16] used the pixels with the highest intensity in hazy images. Then, the top 0.1% of the brightest pixels were selected in the dark channel. However, the above two methods were influenced by white objects. atmospheric light A0 Kim et al. [14] selected the atmospheric light in a hazy image using a hierarchical searching method based on the quad-tree subdivision. In this approach, an image is repeatedly divided into four rectangular regions. The brightest region is chosen as atmospheric light according to the threshold. This method is reliable; however, it employs only the average gray as the criteria and results in white regions. To improve the positioning accuracy and robustness, an additional channel method is proposed based on quad-tree subdivision; this method is based on the experience knowledge that the sky areas are mainly distributed in the middle or upperparts of images. First, the hazy color image is transformed to a gray image, and then, the image is divided into four parts x,i ∈ [1, 2, 3, 4] represents the regions of upper left, upper right, bot-tom left and bottom right, respectively. In addition, n is the level of subdivision, where n =1 represents the first subdivision on the source image[1]. The average gray value of each region S(xin) is defined as the score of this region x, and the formula is expressed as,

S(xin) = mean(I(xin)).

If the highest score region of the first subdivision is on the upper-half of the image, then this region will be the new area that is divided into four smaller blocks using the quad-tree method for the next iterative step. Until the score in the selected area is less than a predefined termination threshold. Thus, the final region is obtained. However, if the highest score region of the first subdivision is on the bottom-half of the image, then the upper-half regions (x) will be calculated with a weight coefficient η. Then, the scores are compared, and the region with the highest score is selected for the next subdivision. If the region is still on the bottom-half of the image, then this region will be the new area that is iteratively processed using the quad-tree method until the final region x is obtained. Otherwise, except to obtain candidate x, the new highest score region on the upper-half part of the image will be subdivided to obtain another can-didate final region x_final, which is called the additional channel. There is an absolute termination condition in the above quad-tree subdivision process; that is, if the difference between the maximum average gray value and the second highest average gray value is less than S, then the region with the highest score will not be divided further without considering whether it reached the setting size.

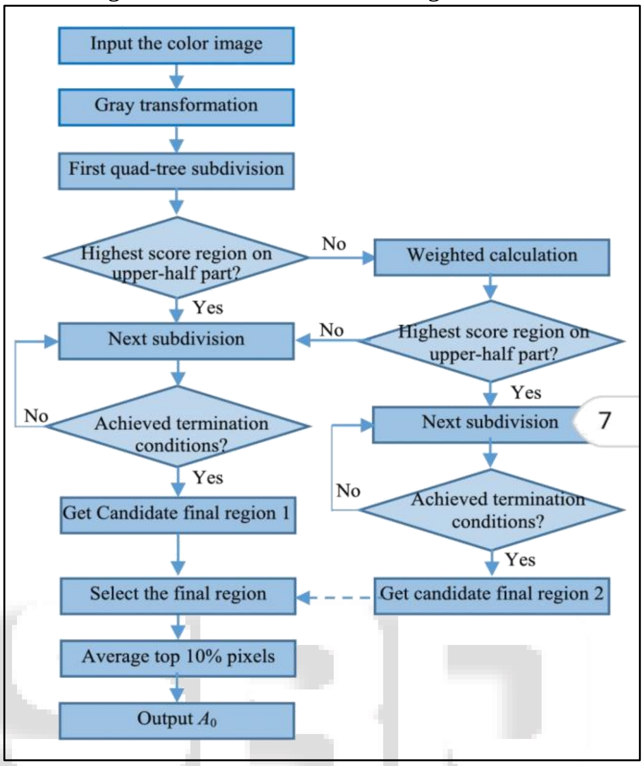

Fig. 2: Flowchart of the method for estimating atmospheric light. (Wencheng Wan et.al, 2017)

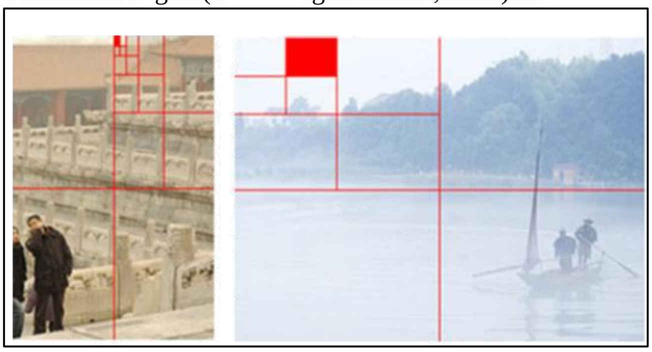

Fig. 3: Sky region positioning using the proposed method. Subdivision of "the forbidden palace". (b) Subdivision of "Lake". (Wencheng Wan et.al, 2017)

B. Homomorphic Filtering

This is a generalized technique for signal and image processing, involving a nonlinear mapping to a different domain in which linear filter techniques are applied, followed by mapping back to the original domain. This is sometimes used for image enhancement, simultaneously normalizes the brightness across an image and increases the contrast. It is used to remove multiplicative noise. Homomorphic filtering can be used for improving the appearance of a gray scale image by simultaneous intensity range compression (illumination) and contrast enhancement (reflection).

$$m(x, y) = i(x, y) . r(x, y)$$

where m is the image, i is the illumination and r is the reflectance. We have to transform the equation into frequency domain in order to apply high pass filter. However, it's very difficult to do calculation. Therefore, $\ln(m(x, y)) = \ln(i(x, y)) + \ln(r(x, y))$. Next apply high pass filter to the image. To make the illumination of an image more even, the high frequency components are increased and low frequency components are decreased.

$$N(u, v) = H(u, v) . M(u, v)$$

where H is the high pass filter and N is the filtered image in frequency domain. Afterward, returning frequency domain back to the spatial domain by using inverse Fourier transform.

$$n(x, y) = invF(N(u, v))$$

Finally, using exponential function to eliminate the log we used at the beginning to get the enhanced image

$$newImage (x, y) = \exp(n(x, y))$$

An example of an output image that has been obtained after passing through the homomorphic filter is shown in the figure below.

C. For linear transformation - Transmission map estimation

1) Linear Transformation

To estimate the medium transmission map,

$$t(x) = \frac{A-I(x)}{A-J(x)}$$

In color images, since one of the reflection coefficient is very small, numerator and denominator were calculated for 3 color channels.

$$t(x) = \frac{A0 - \min_{c\in\{r,g,b\}} Ic(x)}{\dfrac{(A0- d) * \min_{c\in\{r,g,b\}}(Ic(x)) - \min(\min_{c\in\{r,g,b\}}(Ic(x))}{\max(\min_{c\in\{r,g,b\}}(Ic(x)))) - \min(\min_{c\in\{r,g,b\}}(Ic(x))}}$$

from the above equation, as long as transmission map will be obtained accordingly. As d decreases, the contrast of trans-mission map increases and the degree of dehazing enhances.

2) Processing of brightest region

From the above equation given numerator is always greater than denominator, $t(x)<=1$.If min, $Ic(x)<=0$, here the atmospheric light A0is the brightest region in the image.

3) Gaussian Blur

The transmission rate obtained via the above method is pixel-based, which is greatly influenced by its own grayscale value. Considering that the transmission rate, average filtering is obviously unreasonable because it does not take the weight into account and causes the edges to blur. This means that the closer the relationship is between adjacent pixels, pixel value by the weighted average value of all pixels in the pixel neighborhood, higher the weights should be. Otherwise the weights should be lower. Therefore, the weighted average method should be used. The Gaussian Blur method is being used to replace each pixel value by the weighted average of all pixel values in the neighborhood pixels. It has both isotropic and homogenous properties. Filtered distribution map can be obtained via,

$$t''(x) = t'(x) * G$$

D. Recovery of Haze Free Image

According to the atmospheric scattering model, atmospheric light Aare obtained, the scene radiance can be recovered with the following formula transformed from

$$J(x)= \frac{I(x) - A0)}{\max(t(x),t0} + A0$$

where t0 is a lower bound , which is set to 0.05. In addition, due to the influence of different ambient light on imaging, the brightness of some images is low; after the recovery, the overall visual effect maybe darker. Thus, the gray compensation method can be used to adjust the brightness according to the actual situation.

III. EXPERIMENTAL EVALUATION AND RESULTS

Objective evaluation is used so as to have a clear idea about the output being obtained and then the result is being compared with the other methods. Three aspects determine the quality of the output mean square evaluation (MSE), peak signal-to-noise ratio (PSNR) and structural similarity (SSIM) [9] are employed for objective comparison. The expressions of MSE, PSNR and SSIM are as follows:

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [f(i, j) - f\_(i, j)]$$

$$PSNR = 10lg \frac{f max}{MSE}$$

$$SSIM = F (lc , cc , sc)$$

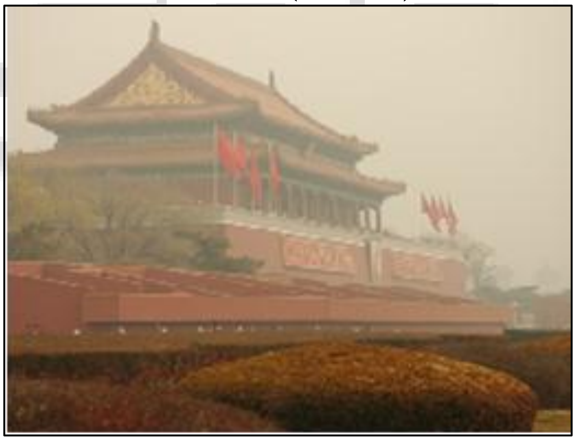

Fig. 4: Input image for both the techniques homomorphic filtering and linear transformation.

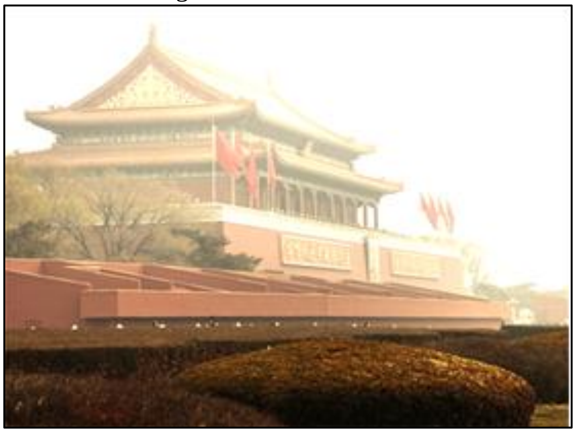

Fig. 5: Output image for the homomorphic filtering technique.

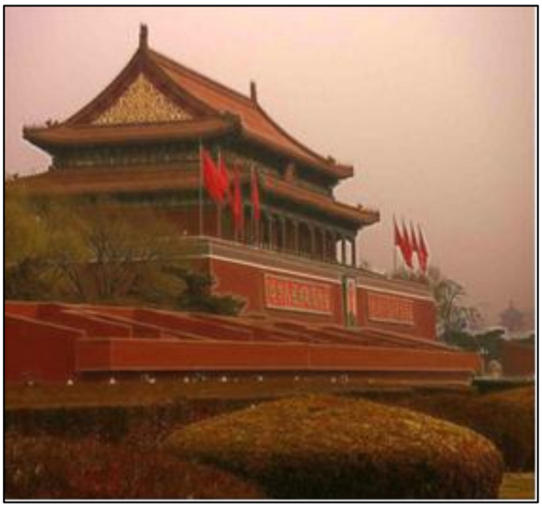

Fig. 6: Output image for the linear transformation technique.

Index	Homomorphic filtering	Linear transformation
MSE	0	13.1527
PSNR	4.5215	14.6739
SSIM	0.0021	0.8059
COMP	4.5215	2.3270

Table 1: Different values obtained when the above input image being applied on 2 methods

IV. Conclusion

This propose method based on homographic filtering and linear transformation mainly works on the principle of atmospheric light estimation via quad-tree subdivision and the applying the homomorphic filtering in one and in the other applying minimum filter and then gaussian blurring is applied using linear equations. The main operation time of the both algorithms was derived from the optimization, while this fast filter makes the filtering work quickly. Therefore, for large image sizes or video from hazy conditions, it can not only improve the dehazing effect but also guarantee the com-putting speed and moreover the edges of the image seems to be more clear than any other techniques . The experimental results show that the both methods can avoid the phenomena of over saturation and halo effects, and the restoration of details and color is very natural, and hence removes the high density haze. The different results obtained via subjective and objective evaluation is shown in the figures and the table which shows the different values.

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