A Simplistic and Efficient Single Image Dehazing Approach

Er.Amit Changotra[1], Er.Shailja Uppal[2], Er.Poonam choudhary[3], Dr.Arnav Bhavsar[4]
[123]Comp.Science and Engg. SIRDA, Institute of Engineering Technology, Sunder Nagar, Mandi-175019
[4]School of Computing and Electrical Engg, IIT Mandi
(E-mail: [1]amitchang115@gmail.com,[2]34shailjauppal@gmail.com,[3] poonamsirda.edu@gmail.com, [4]arnav@iitmandi.ac.in)

***Abstract*—**Dehazing is the procedure to remove the effect of haze from the pictures and enhance the image by restoring typical shades of characteristic scenes. This improves the visibility and contrast of the image. The focus of this paper is to estimates the original image. For this work, initially, the proposed algorithm estimates the air light in the blurred image given on the basis of quad tree decomposition techniques. Then, the proposed algorithm estimates the transmission values range. To measure the contrast, we developed a derivative, using standard deviations. Experimental results show that the proposed algorithm can efficiently remove the haze and recreate the exact details in the original sequences.

Keywords*—Image enhancement, dehazing, contrast enhancement, image restoration.*

I. INTRODUCTION

Image quality is a basic prerequisite in any computerized image application for data extraction and analysis. There has been a growing interest in the analysis of images affected by weather. An important problem is to enhance the images captured in poor weather conditions in order to restore the visibility and contrast of the scene image. This is due to the concern that often, outdoor scene images and videos are often influenced by the poor differentiation due to the adverse climate conditions like dimness, haze and fog. Outdoor images also suffer from low contrast and limited visibility due to haze, small particles such as dust, mist, and fumes which deflect / scatter light from its original course of propagation. The scattering of particulate in visibility causes more serious damage than the absorption of light. Thus, the image loses contrast and color fidelity, and the visual quality of the scene is reduced.

In this regard, Haze removal techniques are essential for improving the visibility of images. Restoring hazy images is a challenging task and various sophisticated methods have been reported for the same. Most of these approaches are based on complex energy minimization or learning-based methods, which are often inefficient.

This could be due to the fact that the image dehazing task involves estimating multiple unknown parameters, which are interdependent. In addition to computing the unknown image, the two important components of the dehazing task involve a) Air-light estimation and b) Estimating a transmission parameter (as discussed later in the paper), which may vary with image locations.

One of the few efficient methods for dehazing is reported in [8] which decouples the airlight estimation and transmission parameter estimation. However, the process of estimation of transmission parameter is still rather intensive involving optimization based on image histogram. In this paper, we adapt this approach to further simplify the task of transmission estimation based on computing image standard deviation, so that the overall approach is simpler and more efficient, nevertheless yielding sufficiently good results. Furthermore we also simplify the process of local dehazing by observing that typically haze varies along the vertical axis of the image, and local regions can be considered only along these axis.

Thus the contributions of this study are:

- A simplistic transmission parameter estimation approach based on image standard deviation
- A simplistic region based dehazing, where the regions are considered along the vertical axis.
- Demonstrating the approach for dehazing videos.

This paper is organized as follows: Literature survey is discussed in Section II. Section III describes the haze modeling. Section IV covers the Airlight estimation and Section V specifies the estimation of the transmission parameter. In section VI we discuss the region based dehazing strategy. In section VII Experiments and results are discussed. Finally, the paper is concluded in section VIII.

II. LITERATURE SURVEY

In this section, we discuss some popular work on image dehazing, including the approach in [8], which we adapt in this work.

Narasimhan and Nayar [2] examine color variations in the scene under various climate conditions which are dependent on the dichromatic atmospheric dissipating model proposed in [4]. They compute the 3D structure and restore sunny morning scene hues from at least two climate pictures [4].However, they assume that there are no atmospheric scattering properties.

The polarization based method[5] improves brightness using two or more photos taken with different degrees of polarization. In [7], [1] variations are obtained in different images of a similar scene in different climatic conditions.

In [3] an automatic technique that only requires a single image input is presented. There are two observations about the method. First, clear day images are more variant compared to images of bad weather and secondly the air-light, whose variant generally depends on the distance of the scene to the observer, tends to be smooth. The work in [3] is based on Markov random fields (MRFs) dependent on these two perceptions. The outcomes have larger saturation values and may contain discontinuities in radiance.

R.Fattal [6] estimates visual and medium albedo transmission under the assumption that transmission and surface shading is locally unrelated. This approach is yields good quality results. However, this approach cannot recover the heavily blurred images (i.e. dense foggy images). A depth based method in [11] requires data from client inputs or known 3D models.

In [8] in view of perception that a foggy picture has low contrast, the authors attempt to restore the natural image by improving the contrast. This is a relatively efficient approach where initially estimate the air-light of foggy image based on the quad tree subdivision of image. Then, the transmission map is estimated and used to improve the contrast of output image. While the airlight estimation is efficient, as indicated earlier, the operation for transmission estimation involves computing histogram for transmission values; an relatively time-consuming process. On the other hand, in this work we formulate a function to measure the contrast based on the standard deviation and histogram uniformity.

We now discuss the methodology in the sections below, starting with the modelling of the haze phenomenon, which establishes the unknown variables to be estimated in the task.

III. HAZE MODELING

The brightness observed in the hazy image can be modelled based on the atmospheric optics [6, 7, 11].

$$Ip = tp.Jp + (1 - tp).A \tag{1}$$

Where Ip is an input hazy image, Jp is the original color, A is the air-light and tpin [0, 1] is the transmission of the light reflected by the object.

Based on the constant transmission assumption, the haze modeling equation can be written as:

$$Jp = \frac{Ip - A}{t} + A \tag{2}$$

Clearly, to recover Jp, one requires the knowledge of the Air-light (A) and transmission parameter(t). Considering that we only have the observation Ip as input, the airlight and the transmission parameter also need to be estimated which can then be used recover the original color Jp from the observed image Ip.

IV. AIRLIGHT ESTIMATION

The existence of particles in the aerosol those generated by the haze effect on the quality of the image. In this case, when the image is taken, the camera absorbs the light scattered by these atmospheric particles, which is called as airlight.

Airlight or haze is the color we see when we look at distant objects. This visible effect is due to the scattering of light by the atmosphere towards the viewer. The distant regions typically correspond to sky or clear space, which in daylight images is typically bright. However, if only the brightest pixel value is chosen as airlight directly, the brighter objects in the scene and bright pixels due to noise, may cause an erroneous estimation of the air-light. Thus, we use an hierarchical searching method [8] which is based on the quad tree decomposition [9] to estimate the air-light value. We discuss the algorithm below:

Airlight estimation algorithm:

Step 1: An input hazy image is firstly decomposed into four patches or blocks.

Step 2: Evaluate the mean of every pixel value of each block and select the block of a maximum mean value and then again decompose it into four blocks.

Step 3: Follow the same procedure until the size of a block is less than or equal to a pre-determined size. The final value of the maximum block mean is considered as the Airlight value.

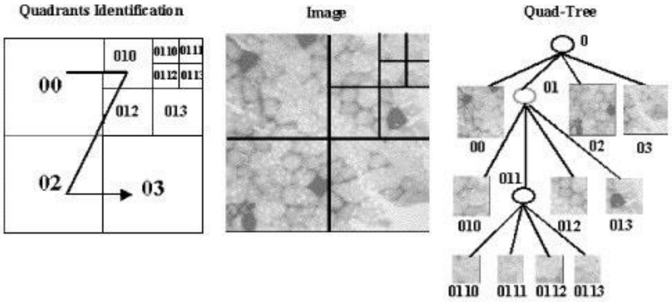

Figure 1: Quad tree decomposition technique ([9]).

V. TRANSMISSION MAP PARAMETER

The transmission map describes the portion of the light that is not scattered and reaches the camera. Since the map is a continuous function of depth, it thus reflects the depth information in scene. After the estimation of Airlight, we estimate the transmission map parameter. The transmission map parameter (t)should be decided in such a way that the dehazed picture has a good contrast, but which is not too high which can make the dehazed image unnatural.

In [8], the strategy for estimating the transmission parameter involves computationally intensive operations such as repeated histogram computation, and minimizing a cost function. More specifically, firstly, a scaled standard deviation as a function of (t)of luminous component of the dehazed values is computed. The second criteria for estimating the transmission parameter is to consider the uniformness of the histogram. A high contrast image typically has an approximate uniformly distributed histogram, whereas the histogram values of a low contrast image are concentrated to the smaller range. Thus, a high contrast image has a large standard deviation but near to a uniform histogram. Therefore, the transmission (t) to minimize the cost function considering both these factors.

In this paper, we use a simpler and efficient strategy which is based on two criteria which only use standard deviation; a much simpler operation than repeated histogram computation. The two criteria considered are:

1. Standard deviation.
2. Derivative of standard deviation.

The first criterion is the standard deviation of the luminance component of the dehazed values $Jp's$.

$$\text{std} = \sqrt{\frac{1}{N}\sum_{p=1}^{N}(Jp,y-\bar{J}y)^2} \qquad (3)$$

Where N is the number of pixels in the image, Jp,y is the luminance part of Jp and $\bar{J}y$ is the mean of Jp,y. Thenthe standard deviation scaled by the value of t is given by

$$\mathit{f}\text{std (t)} = \frac{\sqrt{\frac{1}{N}\sum_{p=1}^{N}(Ip,y-\bar{I}y)^2}}{t} \qquad (4)$$

Where Ip,y is the luminance part of Ip and $\bar{I}y$ is the mean of Ip,y.

The second criterion is the derivative of standard deviation ƒstd (t)can be defined as:

$$d(1{:}\,n-1) = \mathit{f}\text{std (t)}[2{:}\,\text{n}] - \mathit{f}\text{std (t)}[1{:}\,\text{n}-1] \qquad (5)$$

Where d is the derivative of ƒstd (t) (t) along with the $t[1{:}\,\text{n}-1]$, n is the length of ƒstd (t), where n depends on the step quantization of (t) (in this case 0.05). The product of d and ƒstd (t) is also used in the proposed approach to estimate (t),. The plots of ƒstd (t) , its derivative and their product are shown in Fig. 2 - 4.

The derivative of the standard derivation yields the variation in the image standard deviation. To choose a transmission parameter t which yields a balanced contrast in the output image, we suggest that not only the standard deviation at various values of t, but the variation in the standard deviation also be assessed. Thus, we consider the product of equations (4) and (5) as a criterion to estimate the value of the transmission parameter. Note that the computation of both equation (4) and (5) is much less intensive that histogram computation for different values of t.

A step-by-step approach to estimate the value of (t), based on the above definitions are given below.

Steps to estimate the transmission:

Step 1:- Compute the standard deviation of function ƒstd (t)normalize it between 0 to 1 by dividing it by maximum value of ƒstd (t).

Step 2:- Evaluate the derivatives of standard deviation ƒstd (t)along with the values of $t(1{:}\,n-1)$ and divide the derivatives d by the maximum value of derivatives d.

Step 3:- Multiply the derivatives d with ƒstd (t)$(1{:}\,n-1)$.

Step 4:- The value of (t)for which the product in Step 3 is < 0.001, is the value of (t) chosen for the dehazing.

The threshold in the algorithm above ensures that the chosen transmission parameter dehazes the image such that its contrast (indicated by the standard deviation) is not very high (so as not to yield an unnatural image), but is also not too low (so as to yield sufficiently good dehazing).

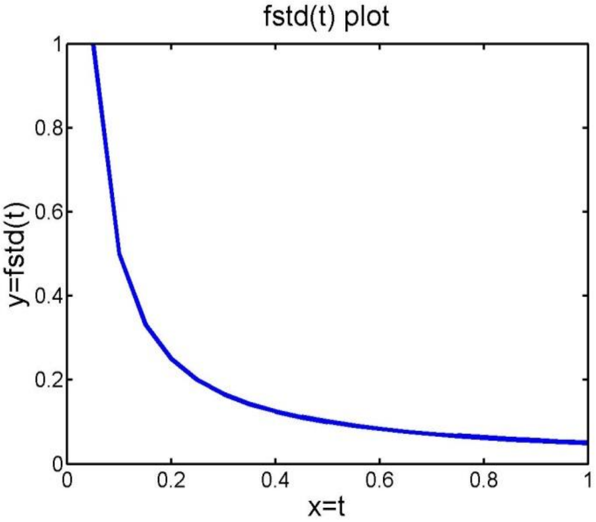

Figure 2: Plot ƒstd (t) and (t).

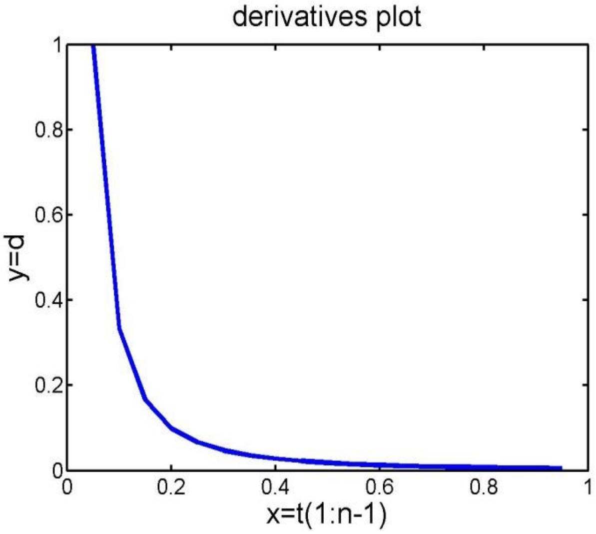

Figure 3: plot the derivative and $t(1{:}\,n-1)$

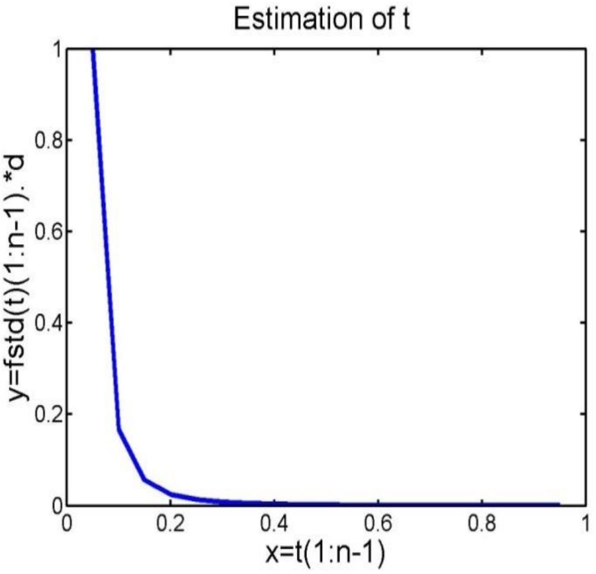

Figure 4: plot the $t(1{:}n-1)$ and fstd $(t)(1{:}\,n-1)*$ d.

VI. REGION BASED METHOD

If the same airlight A and transmission (t) parameters are chosen for the complete image, the dehazed image can have some regions excessively dark or some regions where the details are not clearly enhanced. To avoid this some perform local dehazing. We realize that for natural images as the haze phenomenon typically varies from top to bottom of the image (i.e. across rows, and not so much across columns), instead of considering very small local regions, we can consider larger regions consisting of some rows but all columns. Thus, in the proposed patch based method the input image is split into regions only across the vertical directions, and each such region is separately dehazed.

In this work, the input hazy image is divided into overlapping regions (only 2 to 3) are shown in Fig. 5. This method is effective as for every region air-light and transmission is calculated individually so that it covers every region of the scene (e.g. top region and bottom region). The proposed algorithm is applied on these patches.

- Estimate the air-light of every region using quad tree subdivision.
- Estimate the transmission parameters.

After the above mentioned steps, calculate the mean of overlap regions of dehazed patches and assign these patches to a blank image. Finally, we have an effective dehazed.

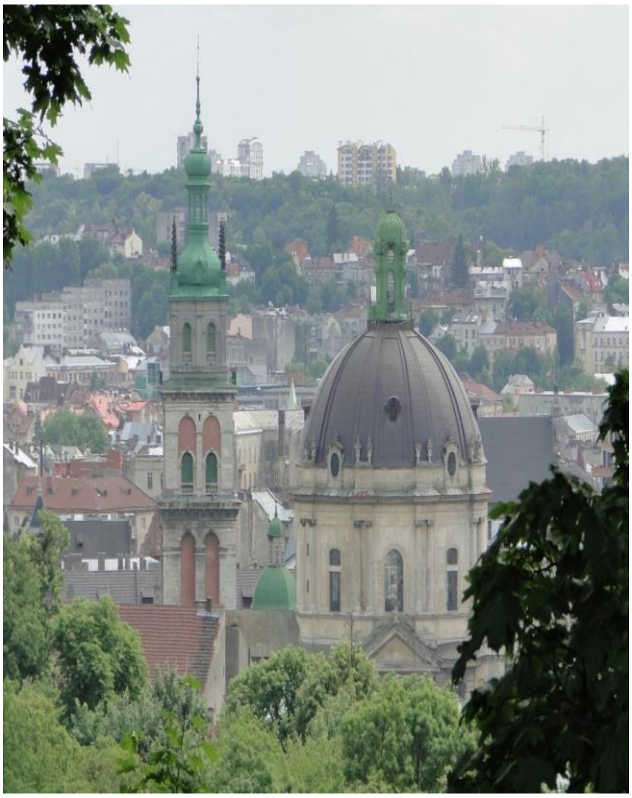

Figure 5(a): A hazy image

Figure 5(b): Patches of an image

VII. EXPERIMENTS AND RESULTS

The performance of the proposed algorithm is evaluated on various test images. Various hazy input images with low contrast and limited visibility haven been collected and processed with the proposed algorithm. One can clearly note that the proposed approach restores the contrast as well as removes haze very effectively shown as given below figures (i.e. Figs. 6 - 9). For instance, in Fig. 6 we see that the proposed algorithm removes the haze and reconstruct the fine details of grass and trees clearly. In Fig.7 one can observe the better reduction in the haze and improvement the visibility of mountains, via the proposed method. In Fig.8 improve the details of flowers. In Fig. 9, the global dehazing results in some dark some regions but in the region based method, the contrast is restored in a more balanced manner. Finally, we also apply the dehazing method to videos. A video captured in outdoor, typically during winter mornings, frequently yields bad quality due to the bad weather condition which attenuate scene radiance. The proposed dehazing approach is applied for each video frame. Note that the simplistic and efficient computation are particularly advantageous in this case, as one needs to process many frames to dehazed the complete video. Some example frames are shown in Figs. 10 – 11.


Figure 6(a): Input image


Figure 6(b): Global dehazing


Figure 6(c): Region method dehazing


Figure 7(a): Input image


Figure 7(b): Global dehazing


Figure 7(c): Region method dehazing

Figure 8(a): Input image

Figure 8(b): Global dehazing

Figure 8(c):Region method dehazing

Figure 9(a): Input image

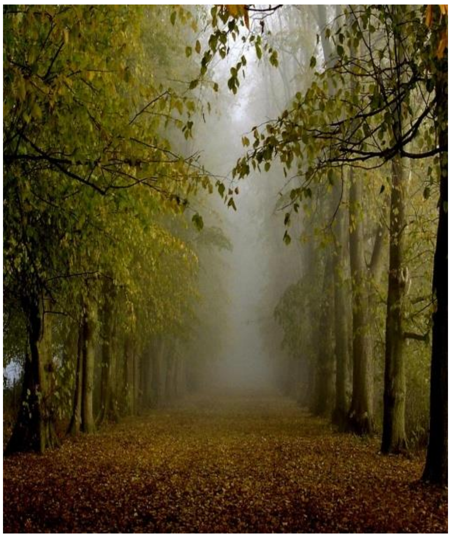

Figure 9(b): global dehazing

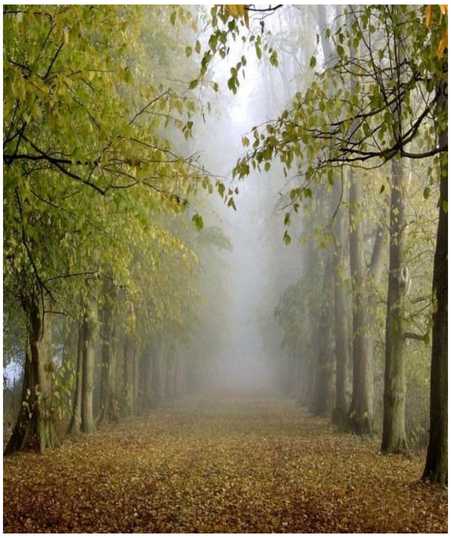

Figure 9(c): Regionl method dehazing

1). Input video frames

Figure 10(a): Frame 1

Figure 10(b): Frame 2

Figure 10(c): Frame 3

Figure 10(d):Frame 4

Figure 10(e): Frame 5

2). Dehazed video frames

Figure 11(a): Frame 1 Figure 11(b): Frame 2 Figure 11(c): Frame 3 Figure 11(d): Frame 4 Figure 11(e): frame 5

VIII. CONCULSION

In this paper, we proposed a simplistic and efficient single image dehazing approach, with primary contributions as the efficient transmission estimation and a vertical region based processing. We demonstrate on various examples that our proposed approach is able to dehaze a variety of images and video frames effectively.

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