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An Efficient Edge Detection Technique for Hazy Images using DCP

[1]Y Saroja, [2]I.sheeba, [3]M. Sudhakar
[1]Assistant Professor, [2] Assistant Professor, [3]Research Associate
[1, 2]CREC, (Autonomous),Tirupati, [3] VIT Chennai
[1]saroja.549@gmail.com
[2]sheebavimalnath@gmail.com
[3]malla.sudhakara2015@vit.ac.in

Abstract— Images of outdoor areas are typically degraded in quality by its turbid medium in the nature such as haze, fog and smoke. The absorption and scattering of light on such kind of images effects the quality of the image. The degraded images will loss the contrast and color artifacts from the original image. Edge detection is another challenging issue on such kinds of degraded images. There are several research works are under progress to reduce the haze exists in the image. Although haze removal techniques will reduce the haze present in the image, the results of those techniques were dropped the natural look of the original image as penalty. We proposed an effective way of finding the edges from the hazy images. Firstly, a dark channel prior method is used to eliminate the unwanted haze from the original image. The statistics shows that this method effectively works for the images taken in an outdoor hazy environment. The key observation of this method is that at least one color channel is having a minimum intensity value in a local patch. The results shows that results of this method have a good results compared to other contrast improvement techniques. Secondly we have applied the Sobel edge detection operator to find the edges of the resultant image.

Index Terms: *Image Enhancement, Hazy images, DCP, Edge Detection.*

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I. INTRODUCTION

Image enhancement is considered as standout amongst the most essential techniques in the image processing applications. The primary aim of enhancing the image is to improve the quality and to increase the visual appearance of a picture to get a better representation than the original image for automated image processing. It is important to upgrade the contrast and to remove the noise present in the image to enhance the image quality. The goal of image enhancement is to process the one image so that the result is apparently better than the original image for several applications such as edge detection, pattern and various object detection and recognition [1, 2]

In real time the images captured in outdoor having haze that obscures scenes, decreases visibility and changes the hues in the image. The quality degradation is annoying problem for the photographers while taking the picture. It is additionally dangerous threat to reliability in numerous applications such as object detection, outdoor surveillance and aerial imaging etc. hence, it is very important to remove the haze present in the image in several computer vision applications.

Images of outdoor areas are typically degraded in quality by its turbid medium in the atmosphere such as Haze, Fog etc. There is a variance in the original look of the image from the captured image by the hazy environment. The irradiance received by the camera from the point where the scene is captured is attenuated and atmospheric air light will effects on the original scene [3]. The images taken from such environment will effects in the contrast and color of the original image as shown in Figure 1.

The main challenge lies in the ambiguity of the problem. Haze attenuates the light reflected from the scenes, and further blends it with some additive light in the atmosphere. The target of haze removal is to recover the reflected light (i.e., the scene colors) from the blended light. This problem is mathematically ambiguous: there are an infinite number of solutions given the blended light. How can we know which solution is true? We need to answer this question in haze removal. Ambiguity is a common challenge for many computer vision problems. In terms of mathematics, ambiguity is because the number of equations is smaller than the number of unknowns. The methods in computer vision to solve the ambiguity can roughly categorized into two strategies. The first one is to acquire more known variables, e.g., some haze removal algorithms capture multiple images of the same scene under different settings (like polarizers). But it is not easy to obtain extra images in practice. The second strategy is to impose extra constraints using some knowledge or assumptionsknown beforehand, namely, some “priors”. In general, a prior can be some statistical/physical properties, rules, or heuristic assumptions. The performance of the algorithms is often determined by the extent to which the prior is valid. Some widely used priors in computer vision are the smoothness prior, sparsity prior, and symmetry prior. In this there are two techniques essentially used.

In the first technique, we achieve a faster speed by solving a large kernel linear system. This discovery is against conventional theories but we can prove its validity theoretically and experimentally. The second technique is a novel edge-aware filter. It is non-iterative and can be computed in real-time, but still exhibits very high quality.

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We find this filter superior to previous techniques in various edge-aware applications including haze removal. Thus, we advance the state-of-the-art in a broader area

a

b

Figure 1: Images from Hazy Environment.

There exists several methods to remove haze using the polarization methods [4, 5] with varying degree of polarization. There are several constraints in [6, 7, and 8] to obtain the results from multiple images under various environmental conditions. We require some depth information from the depth based methods to obtain the result [8, 9].

The remainder of this paper is organized as follows. The Background work on the mathematical equation of haze image are discussed in Section II. The concepts of DCP, Depth map estimation and Sobel edge detection are discussed in Section III. The experiments we have done are discussed in Section IV. Finally, conclusions and future work are summarized in Section V.

II. Background Work

In computer vision, the model generally used to portray the formation of hazy image is shown below:

$$\mathbf{I(x) = J(x)}\ \boldsymbol{t}\mathbf{(x) + A\,(1-t(x))} \qquad (1)$$

Here 'I' denotes the intensity value which is observed, 'J' denotes the scene radiance, 'A' represents atmospheric light and t is the transmission medium. The physical capturing of the equation 1 is shown in Figure 2.The main intension of removing the haze denotes that recovering the 'J' and 'A' from'I'. The terms used here J(x)t(x) shown in (1) denotes the direct attenuation. A (1-t(x)) denotes the Air light. In the homogeneous atmosphere, the transmission t as:

$$\mathbf{t(x) = e^{-\beta d(x)}} \qquad (2)$$

In RGB color space the terms shown in equation 1, such as vectors A, I(x) and J(x) are co planar. The transmission ratio is computed as:

$$\mathbf{t(x)} = \frac{||\mathbf{A}-\mathbf{I(x)}||}{||\mathbf{A}-\mathbf{J(x)}||} = \frac{||\boldsymbol{A}^{c}-\boldsymbol{I}^{c}(\mathbf{x})||}{||\boldsymbol{A}^{c}-\boldsymbol{J}^{c}(\mathbf{x})||} \qquad (3)$$

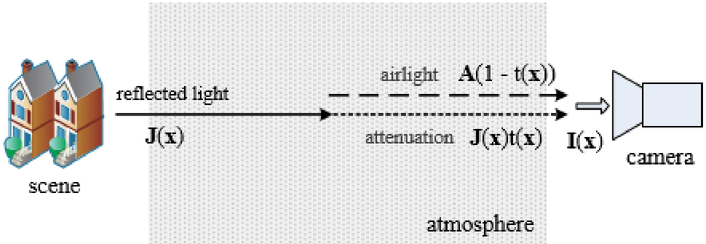

Figure 2. Structure of Physical haze imaging model

III. RELATED STUDY

In this session we will discuss few more details about how to remove the haze exist in the image using Dark Channel Prior (DCP), how to estimate the Depth map and how to apply the Sobel edge detection algorithms.

A. Dark Channel Prior:

The challenging issue in haze removal is due to the ambiguity, basically there is merely a single image as input. The Dark Channel Prior is a technique used to remove the haze present in the outdoor images. The key observation in this method is most of the local patches in the images (those do not contain haze) having few pixels are having very low intensities in at least one color channel such as either Red or Green or Blue. We can say the minimum value of the local patch is very low i.e. it is almost zero. In general for any image J, the dark channel prior can be computed as:

$$\mathbf{J^{dark}(x)} = \min_{c\epsilon\{r,g,b\}}\left(\min_{y\epsilon\Omega(x)}\left(J^{C}(y)\right)\right) = \mathbf{0} \qquad (3)$$

The haze imaging equation is almost similar to image matting equation, Denote the refined transmission map by t(x). Rewriting t(x) and $t^1(x)$ in their vector form as t and t^1, we minimize the following cost function:

$$\mathbf{E\,(t) = t^{T}Lt + \lambda\,(t-\tilde{t})^{T}\,(t-\tilde{t})}. \qquad (4)$$

Here L denotes the Laplacian matrix and λ denotes a regularization parameter, the former term denotes the smooth term and latter denotes the data term.

The DCP is derived from the characteristic of natural outdoor images that the intensity value of at least one color channel within a local window is close to zero. Based on the DCP, the dehazing is accomplished through four major steps: atmospheric light estimation, transmission map estimation, transmission map refinement, and image reconstruction. This four-step dehazing process makes it possible to provide a step-by-step approach to the complex

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solution of the ill-posed inverse problem. This also enables us to shed light on the systematic contributions of recent researches related to the DCP for each step of the dehazing process.

The DCP is based on the property of "dark pixels," which have a very low intensity in at least one color channel, except for the sky region. Owing to its effectiveness in dehazing, the majority of recent dehazing techniques have adopted the DCP. The DCP-based dehazing techniques are composed of four major steps: atmospheric light estimation, transmission map estimation, transmission map refinement, and image reconstruction. This algorithm takes into account both the contrast improvement and color restoration.

The working procedure of DCP is shown in Figure 3. Initially the hazy image captured from the outdoor is considered as input and it will be given for computing the dark channels. We can estimation the transmission function and Atmospheric light. Color restoration algorithm is applied to restore the color. We can quantitatively compare the result with the other state of the art methods.

Consider the image shown in Figure 4. We have taken two input images, one is an outdoor image covering the buildings and roads and the second one is another image which contains some text information on the banner. We cannot clearly say the text present in that if there is more haze. We can recover the haze and can get the natural quality, the result of the dark channel prior is shown in Figure 4(b) and Figure 4(d) for the input images Figure 4(a) and Figure(c).

B. Depth Map Estimation:

Consider a scene point position x at distance d(x) from the observer. Here d is called as depth of the scene and transmission t is related to the depth t.

$$t(x)=\exp\left(-\int_0^{d(x)} b(z)dz\right) \quad (5)$$

Here b is called scattering coefficient, and integral 0 to d(x) is a line between a scene point and the human who is capturing the image. When we consider the scattering coefficient we can rewrite the above equation as:

$$t(x) = \exp(-b(d(x))) \quad (6)$$

Here $d(x) = -\frac{In\ t(x)}{b}$ .we can estimate the depth by unknown scale.

A. Sobel Operator:

In Image Processing, Sobel Operator is mainly used in the edge detection techniques. Actually, it is a derivative operator, to compute the gradients of the image. In all the points of image, it computes the gradient vector or norm of the corresponding vector. In other words, it is a convolution operator to compute the edges in both horizontal and vertical directions and it is less expensive in computations than the other edge detection algorithms and the results of this are relatively crude, specifically for high frequency variation in the original image.

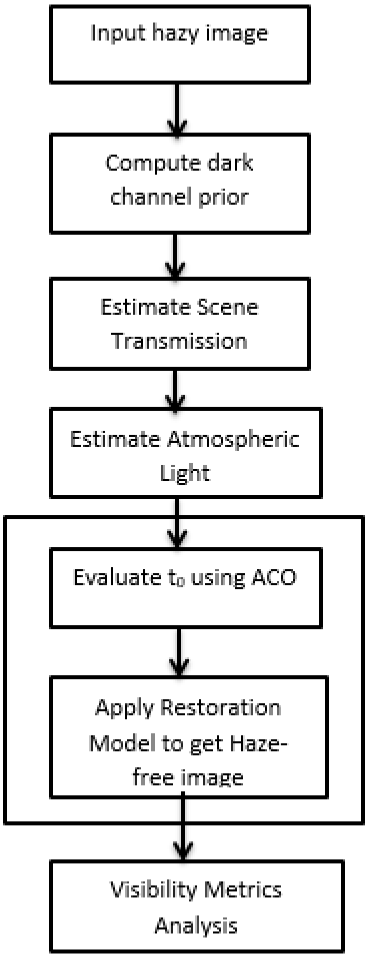

Figure 3: Working Procedure of DCP

The edge detection strategies exist in the literature follow the assumption the, an edge is considered the discontinuity in the neighborhood pixels [10]. This will help us to find the gradients of the image. We can find the derivatives of the intensity values in the complete image to find the maximum derivative to identify the edge in a theoretical manner.The gradient is simply a vector, which intensity values are changed in the X and Y directions [11].

Consequently, we can found the gradients of the images with the following formula:

$$\frac{\partial f(x,y)}{\partial x} = \Delta x = \frac{f(x+dx,y) - f(x,y)}{\partial x} \quad (7)$$

$$\frac{\partial f(x,y)}{\partial x} = \Delta y = \frac{f(x,y+dy) - f(x,y)}{\partial y} \quad (8)$$

Here the ∂x and ∂y measures the distance in both the directions in axis, in general ∂x and ∂y in terms of the number of pixels between the two given points. $\partial x = \partial y = 1$is the point at which pixel coordinates are (I,j) denoted as:

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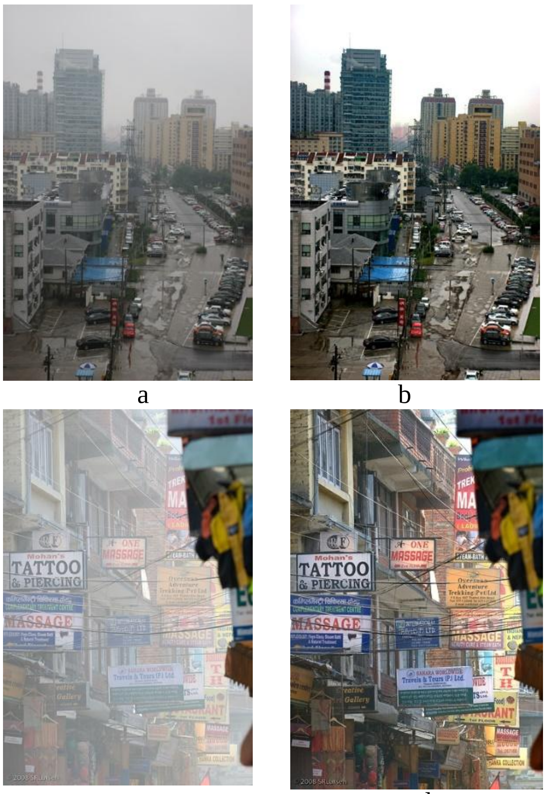
$$\Delta x = f(i+1, j) - f(i, j) \quad (9)$$

$$\Delta y = f(i, j+1) - f(i, j) \quad (10)$$



a b c d

Figure 4: a. hazy out door image b. recovered haze free image c. hazy image containing names d. recovered haze free image

From the above equation, magnitude and the direction of the gradient (Θ) can be computed as:

$$\text{Magnitude} = \sqrt{\Delta x^2 + \Delta^2 y} \quad (11)$$

$$\Theta = \tan^{-1}\frac{\Delta y}{\Delta x} \quad (12)$$

The derivative masks which convolve with image are:

$$\Delta x = \begin{bmatrix} -1 & 1 \\ 0 & 0 \end{bmatrix}$$

$$\Delta y = \begin{bmatrix} -1 & 0 \\ 1 & 0 \end{bmatrix}$$

Similarly there are various masks are presented to find the edges from the given image [12, 13]. Robert's edge operator will consider the following masks:

$$\Delta x = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

$$\Delta y = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

The Sobel Operator mask considered as:

Algorithm: Sobel
Input: Two Dimensional image
Output: Two Dimensional image having only edges
Step 1: Read the input image
Step 2: Apply mask in both directions such as Gx, *Gy*to the input image
Step 3: Apply Sobel edge detection algorithm and the gradient
Step 4: Masks manipulation of *Gx*, *Gy*separately on the input image
Step 5: Results combined to find the absolute magnitude of the gradient. $|G|=\sqrt{Gx^2 + Gy^2}$
Step 6: the absolute magnitude is the output edges

Figure 5: Sobel edge detection algorithm

$$\Delta x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$\Delta y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

The algorithm of Sobel edge detection algorithm is shown in Figure 5. Initially the gradients are computed in both direction and we apply Sobel edge detection algorithm on the gradient compute the magnitude and the angle of direction of the edge.

We have applied the Sobel operator on the gray scale image and the edge detection result can be observed in Figure 6.

a b

Figure 6: a. Input image b. Combined result of Sobel operator in X and Y Directions.

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IV. RESULTS & DISCUSSION

This section shows our works on the Dark Channel Prior and the edge detection algorithms. Our work has done on OpenCV environment using Python. First, we have applied the DCP to the Hazy image. Figure 7(a) is the input image, we can observe that how the image is appeared. It is completely covered with white pixel values in the front end. Figure 7(b) is the gray scale image converted from the input image. Figure 7(c) is the Sobel edge detection result. It is clear that most of the edges are not clear in the result, hence most of the input image is covered with haze. Hence we applied first DCP to the input image, later we applied the Sobel edge detection on the dehazed image. Figure 8(a) is the dehazed image and Figure 8(b) is the gray scale image and Figure 8(c) is the Sobel edge detection result. Our subjective comparison shows that the edge detection is better than the one which is applied directly without applying DCP

a

b

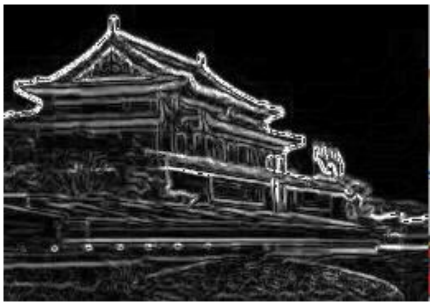
c

Figure 7: a. Hazy image b.Grayscale image converted (a) c. Results of Sobel.

There are several methods exists in the literature to remove the haze present in the image. Fattal [14] and Tan [15] has done their research work to dehaze the image. Figure 9(a) is the input image and Figure 9(b) is the result of Fattal and Figure 9(c) is the result of Tan and Figure 9(c) is the Dark Channel Prior result.

a

b



c

Figure 8: a. Dehazed image using DCP b. Gray scale image of (a) c. Result of Sobel.

In addition, we have shown the depth map by taking the input image with different haze levels. Figure 10(a), Figure 10(c) and Figure 10(e) shows the various levels of input hazy images and Figure 10(b), Figure 10(d) and Figure 10(f) are their compute depth maps respectively.

Quality Measurements:

The comparison of various image enhancement techniques based on histogram equalization is carried out in an objective manner for gray scale images. Quantitative performance measures are very important in com-paring different image enhancement algorithms. Besides the visual results and computational time, our evaluation includes Entropy or Average Information Contents (AIC). We have computed the Mean Square Error and Peak Signal Noise

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ratio and Entropy for the image to show our result objectively.

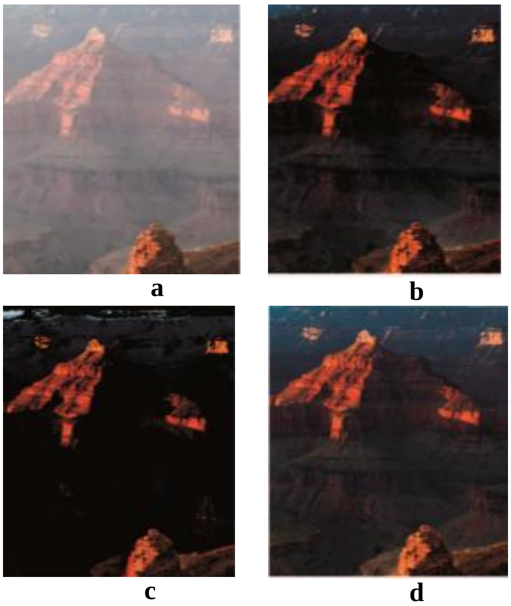

Figure 9 : a. input image b. Fattel result c. Tan result d. DCP Result.

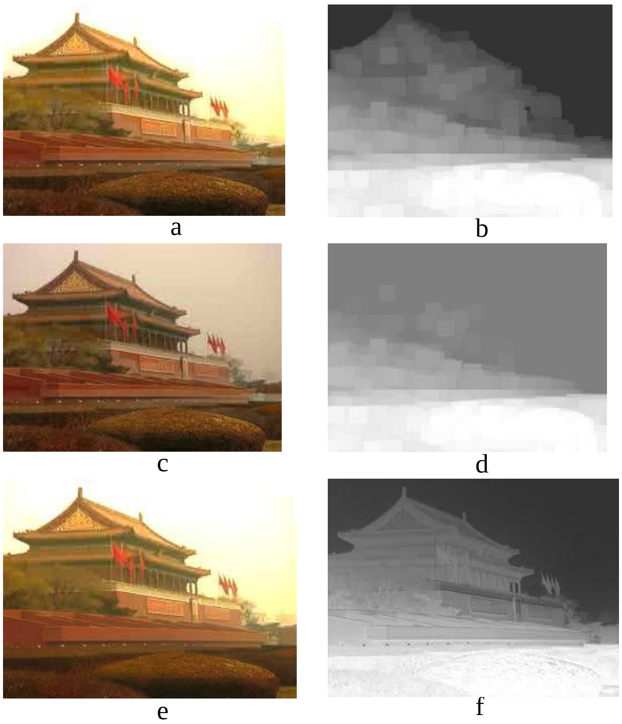

Figure 10: Depth estimation results for different haze levels

The Mean Square Error can be computed as:

$$\text{MSE} = \frac{1}{NXM}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}[X(i,j) - Y(i,j)]^2$$

The value of the MSE should be always minimum and PSNR should be maximum for the better results. Entropy or Average Information Content is used to measure the total information in the image. The higher value of Entropy indicates the richness of the details in the output image. A Higher value of the Entropy indicates that more information is brought out from the images and it can be computed as:

$$\text{AIC} = -\sum_{k=0}^{L-1} P(k)\log P(k)$$

V. CONCLUSION

In this paper, we have used to find the edges present in the hazy image. Firstly, we have used the dark channel prior method and a haze removal algorithm to remove the haze exists in the image. This is a novel and simple technique and giving a best results compared to other haze removal algorithms. We have shown few subjective experiments on this work and also computed the depth map of the image. We have not focused on the running time for this algorithm. Secondly we have used Sobel Edge detection algorithm to find the edges from the dehazed image. The subjective comparison shows that the results are far better than applying the edge detection algorithm on the input image directly. We have compared our work with second order derivate such as Laplacian. The other edge detection algorithm such as Robert's, canny edge detection algorithms should be compared to find the efficient results and this will be considered as our future work.

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Authors Profile:

Mrs. Y Saroja is currently working as Assistant Professor at the department of Computer Science and Engineering in CREC Tirupathi, (Autonomous). She received her master’s degree from JNTUA University in the year of 2012 and Bachelor’s degree from JNTUH University in the year of 2008. She has 3 years of teaching experience and taught various subjects in computer science stream and organized various national conferences and workshops in the organization. Her research interests are Image processing, Computer Network and knowledge engineering.

Mrs. I.Sheeba is currently working as Assistant Professor at the department of Computer Science and Engineering in CREC Tirupathi, (Autonomous). She received her master’s degree from JNTUA University in the year of 2006 and Bachelor’s degree from JNTUH University in the year of 2004. She has 10 years of teaching experience and taught various subjects in computer science stream and organized various national conferences and workshops in the organization. Her research interests are Image processing, Network security and knowledge engineering.

Mr. M.Sudhakar, currently working as Research Associate at VIT University, Chennai Campus. He received his master’s degree at the school of SCSE from JNTUA University in the year 2012. He received his Bachelor’s degree in computer science and engineering in 2010. He has published various national and international journals. His research interests are image analytics, and image enhancement and recommender systems.