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# Single Image Dehazing By Adaptive Restoration Factor in Dark Channel Prior

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*Abstract-* **Now a days capturing images have shown a variety of problems due to environmental conditions, which occurs mainly suspending particles. Suspending particles are in many form like mist, haze, fog, rain, snow etc. these hazards are causes many problem like tracking or capturing of original images. The degraded images directly affect the quality of images in form of efficiency. Due to hindrances of clear observation of object they also degrades the performance of computer vision. The affected images have some pixels with very weak intensities. Through this technique the thickness of haze can be directly obtained. After applying respective algorithm we can get good quality haze free images.**

***Keywords— haze, hindrances, Single image.***

## I. INTRODUCTION

In digital image processing "image dehazing" is a common problem. Images taken in outdoor scenes are often degraded because of dust, mist, fog, etc. present in the atmosphere which spread and absorb light before reaches to the sensor. So, the visibility of the image scene will be excessively challenged. In transportation navigation, surveillance etc. requires the precise information for their appropriate analysis. Thus dehazing becomes an important part of such image restoration. The atmospheric scattering model is usually used in almost all established methods to describe the formation of foggy or hazy images.

Haze removal methods can be divided into two categories, either based on additional data or using a prior assumption. Techniques that rely on additional information contain: using multiple pictures of exactly the same scene and applying various degrees of polarization [1] [2], multiple images taken throughout various weather conditions [3] and techniques that need user provided depth information [4] or a 3D model [5]. The extra information required by these methods is often not available, although they can achieve good results. Therefore a more flexible method which is preferable with restricted prior information is single image dehazing that is applicable and helpful in many image processing scenarios. Single picture haze removal is more successful these days because these methods are based on stronger prior or assumption. Tan [6] Observed that the hazy free images must have higher contrast as compared to hazy images and increased the contrast of the dehazed image. He created a dehazing model based on assumption that the atmospheric light is constant in the haze image model. But the final images often looked unnatural due to oversaturation. Fattel [7] computed the transmission light by using a strong assumption that shading of surfaces and transmission are uncorrelated. This technique is based on color information and thus cannot be applied to grey images and also fails when images are degraded by dense haze because hazy images are colorless. He et al. [8] proposed a straightforward but powerful method, i.e. Dark channel prior. This method restores haze free images with very few halo artifacts. This method is based on the assumption that, in case of haze free outdoor images most of the non-sky patches have at least one out of three color channels (i.e. red, green, blue ) containing low intensity pixels. It's among the most powerful haze removal methods used these days, and produces outstanding results by combining with soft matting. The dark channel prior method may be invalid when the scene object is similar to the airlight. In [9] Jin-Bao Wang et al. improve the dark channel prior by working on two factors. Firstly, they improve the transmission map, which reduces the processing time. Secondly, they drive a new method to select the atmospheric light value. Thus, they reduce the effect of a white object or sky areas on the whole image and produce a clear haze free image. But for restoration of hazy images they fixed a 0.1 value.

In this paper, a novel image dehazing algorithm based on the work of Jing-Bao Wang [9] and He [8] is proposed. This proposed algorithm is divided into two steps. In the very first step dark channel prior [9] is applied to compute dark channel in the image and to estimate transmission map. In the second step, ant colony optimization algorithm is applied to calculate the best restoration factor for each hazy image which lies in the range of 0 to 1. In all previous work the restoration factor is same for all kind of hazy images. But, as the amount of haze differs in different circumstances, the restoration factor should also change according to the degradation level in images. Here an iterative approach is used to select the best restoration factor to produce clearer images.

This paper is structured as: In section 2, we describe the formation of hazy images. In section 3, the proposed algorithm is described. In section 4, experimental results are reported. In section 5, comparison with previous methods is done and in section 6, we have concluded our paper.

## II. MATHEMATICAL MODEL OF HAZY IMAGE

In computer vision, atmospheric scattering model is used to describe the formation of a hazy image as follows [10]:

$$I(x)=J(x)t(x)+A(1-t(x)) \tag{1}$$

Here, I(x) is the observed hazy image, J(x) is the scene radiance, A is global atmospheric light and is the scene T(x) transmission coefficient (describe part of light that is not scattered). The first term J(x)t(x) is the direct attenuation, which reduces the contrast of theimage and the second term A(1-t(x)) is local atmospheric light which increases whiteness in the image.

A hazy image is a mixture of atmospheric light and direct attenuation. The aim of haze removal method is to recover J(x), A and t(x) from I(x). In case of homogeneous atmosphere, transmission can be represented as:

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

Here β represents the scattering co-efficient and d(x) is the depth of the scene at point x, which represents the distance between an object in the image and the observer.

## III. PROPOSED METHOD

The proposed algorithm combines dark channel prior [9] with ant colony optimization [11]. This algorithm takes into account both the contrast improvement and color restoration. The working of the proposed algorithm is explained in figure 1.

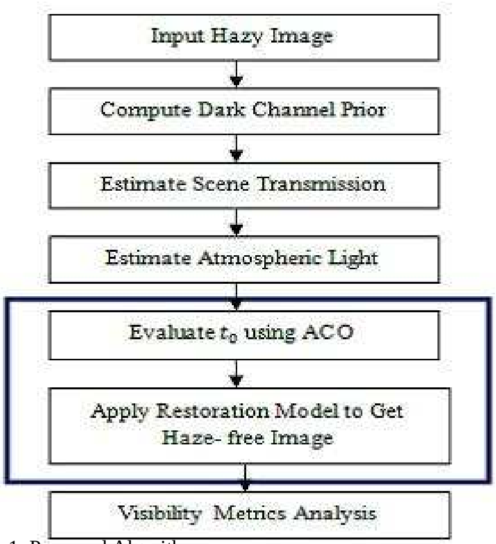


Figure 1: Proposed Algorithm

### *A. Dark Channel Prior*

The dark channel prior technique proposed by He [8] is a common method for haze removal used these days. Most of the haze free outdoor images contain colorful items or areas and shadows. So the majority of the patches in such images contain one or more of the three colors channels, i.e. Red, green and blue low intensity pixels and may be close to zero. The dark channel of a haze free image J(x) is given by below equation:

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}} J^c(y)\right) \tag{3}$$

Here $J^c$ is a color channel of *J(x)* and Ω(x) is a local square patch centered on pixel x. A dark channel in the picture is the result of two minimum operators. In case of haze free outdoor image, the intensity of *J(x)*'s dark channel is very low and tends to zero:

$$J^{dark} \longrightarrow 0 \tag{4}$$

However, in case of foggy or hazy weather the minimum intensity of the dark channel in hazy images is not zero because fog as light scattering effect adds atmospheric light.

### *B. Transmission Estimation*

The haze imaging eq. (1) is normalized using constant atmospheric light A and represented as [9]:

$$\frac{I^C(x)}{A^C} = t(x)\frac{J^C(x)}{A^C} + 1 - t(x) \tag{5}$$

Here normalization operator is independently applied to the three (red, green, and blue) color channels. Further it is assumed that the transmission T(x) in a local patch Ω(x) is constant. Then two minimum operators are applied on both sides of eq. (5).

$$\min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}}\left(\frac{I^c(x)}{A^c}\right)\right) = T(x)\min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}}\left(\frac{J^c(y)}{A^c}\right)\right) + 1 - T(x) \tag{6}$$

According to dark channel prior the dark channel of *J(x)* in haze free image is close to zero. From eq. (3) it is represented as:

$$J^{dark}(x) = \min_{y\in\Omega(x)}\left(\min_{c\in\{r,gb\}}\left(\frac{J^c(y)}{A^c}\right)\right) = 0 \tag{7}$$

Here, $A^c$ is always positive. Transmission T(x) is estimated by substituting the eq. (7) in eq. (6) as:

$$T(x) = 1 - \min_{y\in\Omega(x)}\left(\min_{c\in\{rg,\}}\left(\frac{I^c(y)}{A^c}\right)\right) \tag{8}$$

If the image is captured in good weather conditions, there is still some haze present in front of distant objects. He et al. [8] introduces a constant parameter $w_0 (0<w_0\leq 1)$.

$$T(x) = 1 - w_0 \min_{y\in\Omega(x)}\left(\min_{c\in\{r,g,b\}}\left(\frac{I^c(y)}{A^c}\right)\right) \qquad (9)$$

We fix $w_0=0.95$ in this work.

*C. Estimating Atmospheric Light Value Based On Variogram*

Most of the dehazing algorithms obtain atmospheric light values (A) from image related pixels. Like Narasimhan et al. [4] estimated the atmospheric light value by dividing skyregions in the hazy images. Tan et al. [6] used maximum brightness value as an atmospheric light, but the brightest pixel may reside in white objects. He et al. [8] ranks the brightness values of each pixel in decreasing order and take top 0.1% of the pixels in dark channel position. In [9] introduces a method to choose atmospheric light based on variogram. For original foggy image variance (S) for a single pixel can be calculated as:

$$S = k\sqrt{\frac{(b-m)^2+(g-m)^2+(r-m)^2}{3}} \qquad (10)$$

$$m = \frac{(b+g+r)}{3} \qquad (11)$$

Where m is the average gray value of a single pixel and k is proportionality constant. The variance is compared with a threshold value $\Delta=36$. If $s\leq \Delta$, the brightest point is considered as part of sky area or a white object and this data is discarded. And if $s\geq\Delta$, the value is valid and atmospheric light value is calculated.

*D. Recovering The Scene Radiance By Using ACO*

After calculating global atmospheric light value and transmission coefficient, the final haze free image is represented as

$$J(x) = \frac{I(x)-A}{\max(t(x),t_0)} + A \qquad (12)$$

The direct attenuation can be very close to zero when the transmission is close to zero and the scene radiance is prone to noise. So He et al. [8] and Jin-Bao wang [9] restrict the transmission to the lower bound , and restrict this value. Here we use ant colony optimization (ACO) toselect the value of $t_0$ in the range of 0 to 1. Ant colony optimization algorithm selects best restoration value for each input hazy image. ACO is proposed in 1992 by Marco Dorigo. And this model is inspired from the foraging behavior of real ants. The behavior of ants to search food source is explained as [11]:

1. Initially, all ants search for food in any direction.
2. If any ant discovers food, it returns back to the nest and leaving a trail of pheromone in its path.
3. Usually the other ants tend to follow the already discovered path with strong pheromone.
4. Again, when these ants return back to the colony they strengthen the path.
5. In this way shortest path is more travelled by ants and therefore become more attractive.
6. The long path will ultimately vanish as pheromones are volatile. And ants prefer pheromone rich shortestpath.

In this way, ants choose the optimized restoration value for each input image and produce a high contrast clear image.

## IV. EXPERIMENTAL RESULTS

In our first experiment, we selected images with sky areas for processing. The results are shown in figure 2. In our second experiment we consider satellite and glacier images, the results are shown in figure 3. Third experiment in figure 4 is done with colorful images of natural scenes. In figure 5 results of He's [8], J-B Wang [9] and our proposed method are compared.

Figure 2: The first row (4-6) are satellite and glacier input images and the second row (d-f) dehazed images with our method

Figure 3: The first row (7-9) is natural scene input images and the second row (g-i) dehazed images with our method

Figure 4: From left to right, **(**10**)**Input images, (t)He's result [8],(u) J-B Wang's result [9] and (j) proposed algorithm.

## V. QUANTITATIVE EVALUATION

This section compared our proposed method with the existing methods with help of three parameters: MSE (mean square error), PSNR (peak signal to noise ratio) and RMSE (root mean square error). These are calculated as:

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(f_{ij} - f'_{ij}\right)^2$$

$0 \leq i \leq M\text{-}1,\ 0 \leq j \leq N\text{-}1$ (13)

$$PSNR = \frac{10\log\left((2^n - 1)\right)}{MSE} \quad (14)$$

$$RMSE = \sqrt{MSE} \quad (15)$$

Here, $f_{ij}$ represents the original image, $f'_{ij}$ is the dehazed image, M and N represents size of the image. Proposed algorithm is compared with He's [8] and J-B Wang [9] algorithms. Table 1 has shown results for MSE, PSNR and RMSE for different types images with different methods. It is clear from table 1 and figure 5 that proposed method is giving better results.

TABLE 1: QUALITATIVE ANALYSIS

| Images | MSE | | | RMSE | | | PSNR | | |
|---|---|---|---|---|---|---|---|---|---|
| | He's | J-B Wang | Proposed | He's | J-B Wang | Proposed | He's | J-B Wang | Proposed |
| 1 | 0.0330 | 0.0212 | 0.0103 | 0.1816 | 0.1457 | 0.1016 | 31.4734 | 32.4302 | 33.9953 |
| 2 | 0.0347 | 0.0175 | 0.0136 | 0.1864 | 0.1323 | 0.1168 | 31.3610 | 32.8489 | 33.3919 |
| 3 | 0.1715 | 0.1488 | 0.0885 | 0.4141 | 0.3857 | 0.2976 | 27.8946 | 28.2025 | 29.3295 |
| 4 | 0.0318 | 0.0137 | 0.0112 | 0.1785 | 0.1170 | 0.1056 | 31.5500 | 33.3836 | 33.8288 |
| 5 | 0.0165 | 0.0183 | 0.0108 | 0.1286 | 0.1354 | 0.1040 | 32.9727 | 32.7501 | 33.8954 |
| 6 | 0.0325 | 0.0269 | 0.0225 | 0.1800 | 0.1641 | 0.1501 | 31.5131 | 31.9151 | 32.3009 |
| 7 | 0.0429 | 0.0222 | 0.0196 | 0.2071 | 0.1489 | 0.1400 | 30.9037 | 32.3373 | 32.6030 |
| 8 | 0.0243 | 0.0177 | 0.0159 | 0.1558 | 0.1330 | 0.1261 | 32.1408 | 32.8254 | 33.0590 |
| 9 | 0.0682 | 0.0414 | 0.0274 | 0.2612 | 0.2036 | 0.1654 | 29.8953 | 30.9785 | 31.8793 |
| 10 | 0.0166 | 0.0162 | 0.0102 | 0.1289 | 0.1273 | 0.1009 | 32.9632 | 33.0163 | 34.0285 |

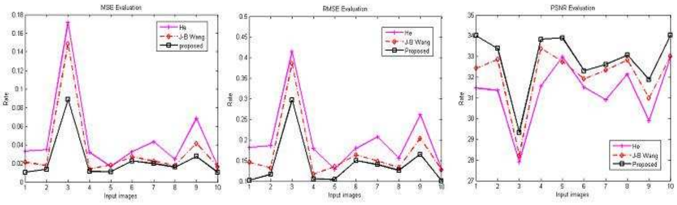


Figure 5: (a) Graph for MSE, (b) Graph for RMSE and (c) Graph for PSNR.

## V. CONCLUSION

In this paper, single image dehazing algorithmis proposed. This algorithm combines ant colony optimization with dark channel prior. Ant colony optimization algorithm is used to select best restoration factor for each hazy image. Experiments are performed on satellite, glacier and natural scene images with or without sky areas; from the experimental evaluation it is defined that our proposed scheme is yielding clearer images than the previous methods. In future, concentration on the identification of other types of noises that are mixed with haze and fog will be attempted.

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