AN IN-DEPTH ANALYSIS OF DARK CHANNEL PRIOR BASED IMAGE DEHAZING

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Abstract: Captured images or videos in bad weather have low contrast and poor visibility as its gets contaminated by atmospheric particles and aerosols; resultant images suffered from color distortion, contrast deduction. The depletion of haze called dehazing which is required to get quality pictures. For various vision applications as object tracking, video surveillance, underwater image enhancement dehazing algorithms have become more beneficial. Single image dehazing methods using DCP has received a great attention, which includes some stages- 1.construction of dark channel, 2. Estimation of Atmospheric light and transmission map 3. Refinement of transmission map, 4. Reconstruction of dehaze image. This review paper has detail survey on DCP method steps and improved version of DCP as IDCP, IDCP with guided filter, DCP with histogram equalization. This paper will help readers in research of DCP based dehazing methods.

Index Terms **- Dark channel prior,dehazing,airlight,transmission map,dehazed image construction,LOS.**

I. INTRODUCTION

Outdoor scene images captured in bad weather conditions are deteriorated by atmospheric particles. Captured image's color quality and contrast are lowered down by smoke, dust, snow moisture, and water droplets etc. which are present in the atmosphere. These all particles are present below 1000m range.

The phenomenon in which clarity of the sky got obscured by the cause of atmospheric particles is termed as haze. The main reason for the occurrence of haze is both direct attenuation and airlight. The factor airlight due to which the whiteness in an image increases is a mixture of both line of sight and the light coming from other directions. Dropping in intensity of a captured image is due to the second factor which is attenuation. Due to this drop, color of an image also degraded. Occurrence of scattering in picture basically depends upon the distance between object and camera. As distance increase, scattering is definitely going to increase that degrade the image quality. So the degradation in image quality is spatially varied.

So, for computer vision systems it is necessary that image features are highlighted and image's visual effects are improved. "Haze removal" or "defogging" is the other names of image dehazing technique. Main motive of this is to minimize the interference which is caused by haze with the help of special approaches. These approaches give useful information and tolerable visual effects. In image enhancement dehazing technique unwanted visual effects are removed. Previous contrast enhancement and noise removing method are different from this technique. The acquisition device and object's distance is the reason on which presence of haze depends and degradation of image pixel also depe`nds on the density of the haze.

However, degradation in image quality is spatial-variable which depends on the unknown scene depth, due to which dehazing is a challenging process. General contrast enhancement techniques depend only on pixels values such as linear mapping, histogram equalization, and gamma correction and ignore the spatial relations.

Video Dehazing is a process to dehaze each and every image/frame of the video. Basically, it's all about separating frames from the video so that dehazing algorithm can be applied on individual frame and after that recombining all dehazed frames to get resultant dehazed video. Video specifications are to be considered before applying proposed dehazing algorithm and sequential results are to be managed properly during video dehazing. In the earlier study multiple images required for dehazing which are polarization based methods [1], depth map based method and multiple images of same scene captured in different weather condition [2].

Tan et al [3] proposed a method based on two prior knowledge for effective single image dehazing i.e. contrast of the foggy image is less as compare to the contrast in clear day image and airlight variations tend to be smooth. This method can process color as well as gray images. Because of sudden changes in depth, halo effects occur which is leading to over color saturation problem.

R.FATTAL [4] has recovered the haze free image by using independent component analysis and markov random field model through which he measured surface albedo and then medium transmission. If sufficient information in regarding of color is present, than this method produced good results. When original assumptions are baseless means heavy haze in the image then image restoration cannot be effectually.

He et al. proposed a novel prior- DCP (dark channel prior) algorithm in which he assumed that some pixels in any one of the color channel has very low intensity. In this method the region has been taken that is not covered by the sky. Transmission map is evaluated accurately. If the areas in the image are brighter as sky, water or may be white then this method may not be valid [5-6].

C.O. Ancuti, C.Ancuti, C.Hermans gives phenomena for restoration of single foggy or haze image. In this phenomena a semi inverse of the original image is produced by applying a single per pixel and hazy regions are also integrate on a per pixel basis. By this algorithm evaluation of airlight contrast and transmission map are implement efficiently. In this method Processing time is less and it provides better results but edges of the image is not preserved [7].

Xiaoyan Yuan et al. defined an improved haze removal method by combining the dark channel prior (DCP) and histogram specification. The image that has low contrast and large background area is cleaned by DCP method then the result has an amorphous. To improve the result he rebuilds the histogram of the image after applying DCP method that changes the intensity and contrast of haze removal image.

Anupama, Nidhi singh,Lavi tyagi [8] introduced a new single image haze removing method for color images hybrid dehazing technique using IDCP with histogram equalization, they introduced HDCP method to remove haze from the color image in which improved dark channel prior is integrated with histogram equalization and then noise is removed by using weighted guided filter. Due to its effective result this method is used for object tracking and traffic sign recognition. Haze free image has clear edges with good contrast.

Xu,et al**.**[9] has concludes that degraded images has poor contrast, to overcome this problem he has defined a method i.e. contrast limited adaptive histogram equalization (CLACHE) method. Nowadays many review papers are available on dehazing mainly enhancement based and restoration based dehazing methods [19].

II. BACKGROUND

In this segment we described how the haze occur by using haze model and removal of haze by using dark channel prior based method algorithms along with steps involved.

2.1 HAZE MODEL

Fig.1 shows the formation of hazy image. Basically, Airlight and Direct attenuation together generate haze.

Haze = Airlight + Attenuation

Mathematically it can be represented as:

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

Where x defines coordinates of image, I represent the hazy image captured by digital camera, J represents the haze free image, t(x) is the transmission map which is the portion of light that is reached on the camera without scattering and A is the atmospheric light. Transmission map depends on the depth of the scene radiance d(x) and scattering coefficient β of the atmosphere which is given as

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

When there is no fog i.e. weather is clear, then atmospheric scattering coefficient $\beta=0$, $t(x) =1$,

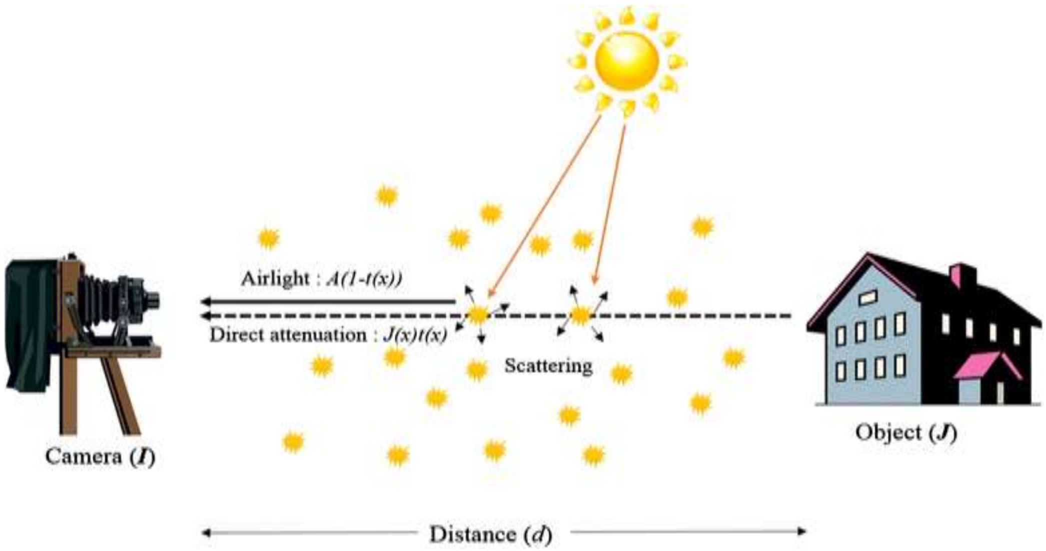

Fig1. Formation of hazy image[22].

I(x) = J(x) i.e. observed image is haze free image. The expression j(x)*t(x) in Eq.1 is direct attenuation that is reduce and second expression A(1-t(x)) in Eq.1 is airlight that is increases as the scene depth increases.

Haze free image J can be recovered by the hazy image I by estimating A and t, can be represented mathematically as:

$$J(x) = \frac{I(x)-A}{t(x)} + A \tag{3}$$

2.2 BASIC ALGORITHM FOR DCP BASED DEHAZING METHODS

In Fig.2 basic steps of DCP based single image dehazing i.e. dark channel construction, transmission map estimation [17], atmospheric light estimation, transmission map refinement and dehazed image construction are described.

2.2.1 Dark Channel Construction

Dark channel is constructed by input hazy image; local patch Ω(x) size is an important parameter for this construction. It is based on the assumption that in an image patch, low intensity pixels i.e. dark pixels has been founded for at least one color channel. A dark channel can be represented as

$$J^{dark}(x) = \min_{y\varepsilon\Omega(x)}(\min_{c\varepsilon\{r,g,b\}} J^C(y)) \tag{4}$$

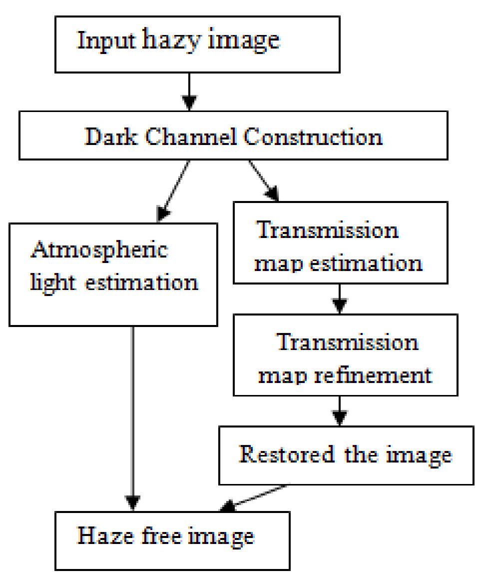

Fig2. Basic block diagram of DCP based dehazing algorithm

$\Omega(x)$ is a local patch at pixel x, $J^C(y)$ is the color channel ($c\mathcal{E}\{r,g,b\}$) intensity of RGB image.

Dark channel can also be estimated by using median operator instead of min operator introduced by Zhang [21], but it is a complex process.

2.2.2 Transmission Map Estimation

For transmission map estimation divide the eq.(1) by A^c as given in a local patch:

$$\min_{y\varepsilon\Omega(x)}\frac{Ic(y)}{Ac}=t(x)\min_{y\varepsilon\Omega(x)}\frac{Jc(y)}{Ac}+(1-t(x)) \qquad (5)$$

It is assumed that in local patch $\Omega(x)$ transmission is constant as t(x).now after applying three color channels:

$$\min_{y\varepsilon\Omega(x)}(\min_c \frac{Ic(y)}{Ac})=t(x)\min_{y\varepsilon\Omega(x)}(\min_c \frac{Jc(y)}{Ac})+(1-t(x)) \qquad (6) \quad \textit{where } c\in\{r,g,b\}$$

J(x) haze free image so dark channel value becomes zero, and then transmission map can be written as:

$$t(x) = 1- \min_{y\varepsilon\Omega(x)}(\min_c \frac{Ic(y)}{Ac}) \qquad (7)$$

For better visibility in the dehazed image a constant

ω is added in the Eq.7 and it can be now presented as:

$$t(x) = 1- \omega \min_{y\varepsilon\Omega(x)}(\min_c \frac{Ic(y)}{Ac}) \qquad (8)$$

Where $0<\omega<1$

2.2.3 Atmospheric Light Estimation

Atmospheric light play an important role in the estimation of transmission map estimation as in Eq.7, most of the previous methods has taken the p% brightest pixels in image. The value of p has been taken 0.1 [10-15] and 0.2 [16] in some DCP based dehazing methods.

Atmospheric light estimation selection can be done on the basis of intensity [6-11] or entropy [13].

When the A is close as the color of the sky in a hazy image d(x) tends to infinity then t(x) becomes zero.

2.2.4 Transmission Map Refinement

Quality of the dehazed image depends upon how much accurate the transmission map, so refinement of t(x) is most important. Blocking artifacts and false textures problems occurs if the estimation of transmission map is incorrect. There are some filters which have been used for refinement.

(i) Gaussian filter(Ga)
(ii) Bilateral filter(Bi)
(iii) Cross bilateral filter(Cr)
(iv) Soft matting (Sm)
(v) Guided filter (Gi)

Gaussian and bilateral filters don't use the hazy image for guidance even as soft matting, cross bilateral and guided filters use hazy image for refine transmission map as guidance image. Refined transmission map is denoted by $t^{\wedge}(x)$. Comparisons between refinement methods can be understood by the following basis:

a) On the basis of time complexity-guided filter performs best.
Gi <Ga< Bi<Cr< Sm

b) On the basis of RMSE value-soft matting method is best when RMSE value is compared.
Sm < Cr < Gi <Bi < Ga

c) On the basis of memory efficiency-Gaussian filter is best memory efficient filter while guided filter is memory inefficient filter.
Ga >Bi> Cr >Sm> Gi

2.2.5 Dehazed Image Construction

Dehazed image can be reconstructed by using Haze model Eq.3, by replacing t(x) by refined transmission map $t^{\wedge}(x)$ and it can be written as:

$$J(x) = \frac{I(x)-A}{\max(t\hat{}(x), to)} + A \quad (9)$$

Denominator value in Eq.9, should always be greater than 0, so to avoid this take a constant to=0.1to 0.75.

III. DCP BASED DEHAZING TECHNIQUES

3.1 DARK CHANNEL METHOD

It is a single image dehazing method based on the assumption that in an image patch, low intensity pixels i.e. dark pixels has been founded for at least one color channel.

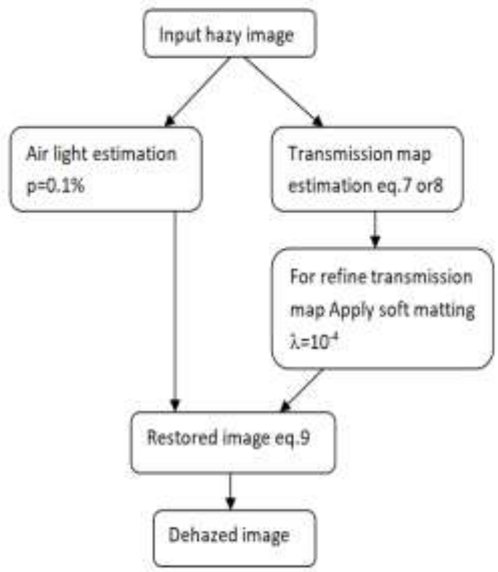

Fig 3: Block diagram for DCP algorithm.

Merits:

i. It can be applied for dynamic scenes because it is a single image fog removal method.
ii. Estimation of transmission map is very precise.

Demerits:

i. Resulted image has halo effects.
ii. Soft matting is used which is a time consuming process.
iii. When the objects in the image have white region i.e. snowy ground, car head lights, then this method is not good.

3.2 IMPROVED DARK CHANNEL PRIOR

This method is improved version of DCP proposed by Yan Wang in 2010[18].In this method bilateral filter is used instead of soft matting. In this patch size is increased 31x31, which play an important role in estimation of air light.

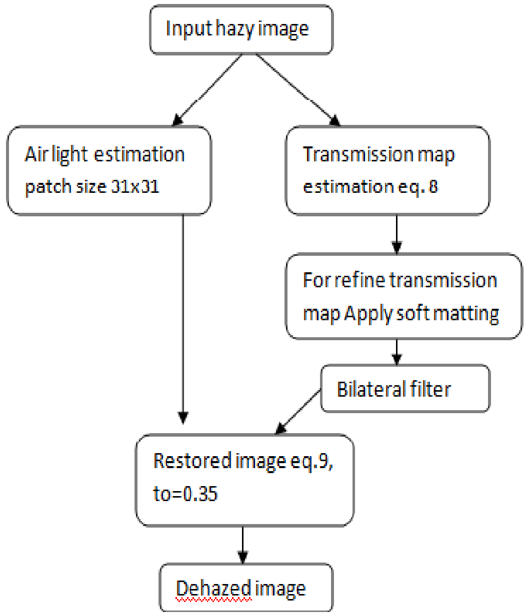

Fig 4: Block diagram for IDCP algorithm

Merits:

i. Air Light estimated precisely.
ii. No use of soft matting, so time complexity is less.
iii. Bilateral filter removes the false color textures problems in the transmission map.

Demerits:

i. Approximation of transmission map is not correctly.
ii. Also generates some halo effects.

3.3 IMPROVED DCP USING GUIDED FILTER

Guided filter is an edge preserving and smoothening filter. It is local linear Filter in which filter output is obtained by using guidance image. Guidance image may be input image or another image.

Main drawback of DCP and IDCP methods is that they generate halo effects which are removed in this method by using guided filter as a refinement of transmission map [20].

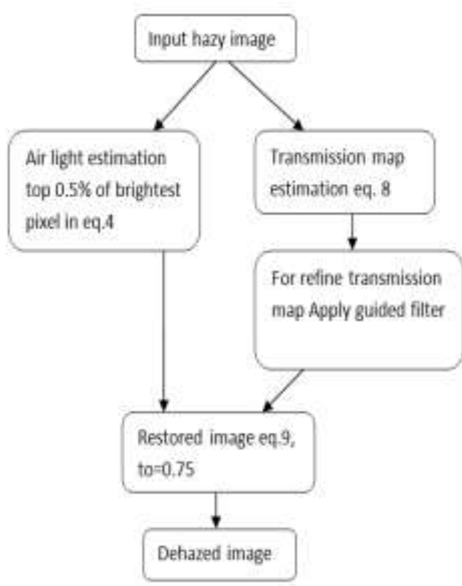

Fig 5: Block diagram for IDCP with guided filter algorithm.

Merits:

i. Refined t(x) find by hazy image, so the Sharpness of the resulted map same as of the hazy image.
ii. Time complexity of guided filter is very less as comparison to soft matting and bilateral filter.
iii. Effectively remove the halo effects.

Demerits:

i. Restored image has overall very low contrast.
ii. Air light estimation is not done perfectly.

3.4 DCP WITH HISTOGRAM SPECIFICATION

DCP provides inaccurate results for an image that has low contrast and large background area, so this DCP with histogram specification method provides good result of recovered image with better contrast.

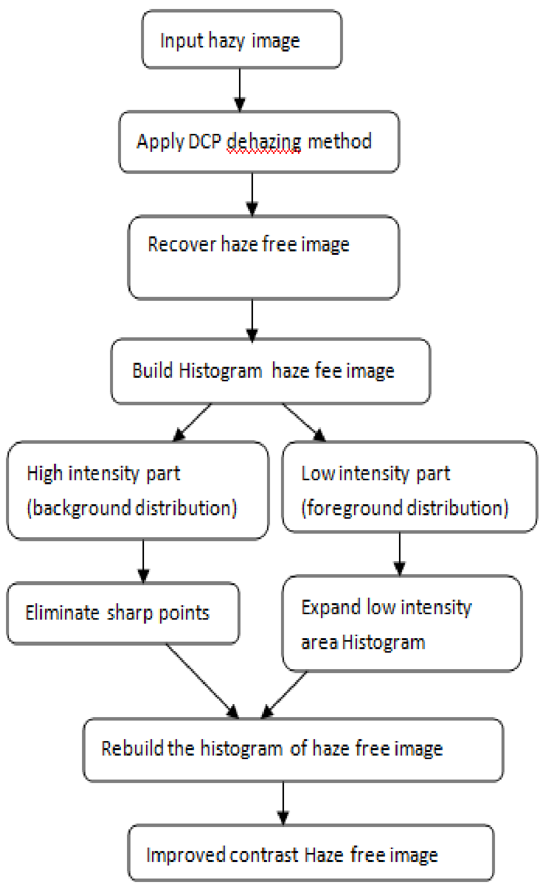

Fig 6: Block Diagram for DCP with histogram specification Algorithm

Merits:

i. Only interested area's intensity change.
ii. Haze free image has better contrast as compare DCP.

Demerits:

i. Time requirement is more.
ii. This method fails in high intensity background region images.

IV. CONCLUSIONS

In this review paper we deeply study an effective dehazing algorithm: DCP based single image dehazing algorithm step by step(construct the dark channel, estimate the atmospheric light and transmission map, refine the transmission map and in last construct the haze free image) and improved version of DCP method. On the basis of merits and demerits of all methods we conclude that IDCP using guided filter is good. IDCP using guided filter is very effective method but guided filter is memory inefficient and time taken by this filter is very less as compare to other filter. Besides less processing time, how to reduce the memory inefficiency and improve contrast gain will be our future work.

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