Design and Implementation of Haze Removal System

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Abstract - *Haze is one of the natural phenomena where turbid medium conceals scenes diminishes color contrast and reduces visibility. Removal of haze from these images is an important challenge, where the dehazed images find applications in automobiles for better visibility and in photography. The main aim lies in improvising the human visibility in the bad weather conditions. In the paper, a dark channel algorithm and median filtering is used to remove the haze from an image. It is seen that the proposed algorithm works for all types of haze in daytime.*

Key Words*: *Dehazing, Airlight, Scene Radiance

1. INTRODUCTION

Low visibility condition is a frequent occurrence. Poor visibility leads to flight delays, diversion, car accidents and also pollution has increased the problem and providing it to be fatal. The task is to deal with situations which reduce human performance due to low visibility. The human eye has a resolution of some 324 to 576 pixels depending upon the angle of vision, but in the cases of haze or other weather conditions visibility is impaired. The main ambiguity involved is the atmospheric light which degrades the image, by scattering the light reflected from the scene of point when a hazy image is captured. The dehazing process is performed by using the dark channel prior algorithms. The visibility matrix if an images is obtained which found to be improvised than previous methods. Multiple image based approach was used for defogging by Narasimhan and Nayar[1].Polarization based vision through haze approach used polarization properties of an image for dehazing by Sehechner[2].The Novel based fast defogging method from a single image of a scene based on a fast bilateral filtering method, but this involved of complexity of obtaining linear functions of a number of input image pixels[3].Image depth based methods, demand some depth information of the images from the user inputs[4].

In this paper we propose a dark channel algorithm for dehazing an image. Dark channel is for outdoor images which is completely a statistical approach. So, the dark channel is estimated for hazy images in which few pixels possess low intensity with respect to any one color channel i.e., RGB plane. The dark pixel estimation provides rough information about the thickness of haze and also about the amount of atmospheric light or air light responsible for dark pixel formation. Further from the results of dark channel, transmission map is estimated which helps to obtain or recover scene radiance. Noise removal involves usage of median filters and visibility metric for the haze free image is calculated by necessary equations.

2. DARK CHANNEL ALGORITHM

The approach involves mainly the application of dark channel algorithm to obtain haze free image with high visibility and color contrast. This also involves the application of Hybrid median filter [5] to remove the impulse noises present in the haze free image, which adds on to the higher visibility metric. The hazy images are described by eqn (2.1),

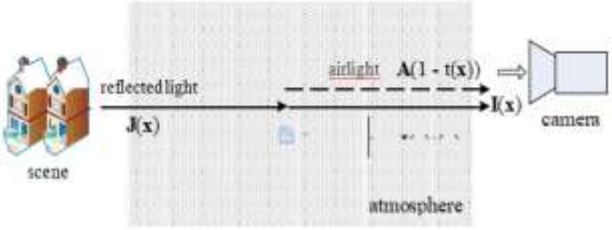


Fig 1: Physical structure of a hazy imaging model.

$$I(x) = J(x)\, t(x) + A\,(1 - t(x)) \qquad (2.1)$$

Where, *I* is the intensity of hazy image, *J* is the scene radians of haze free image, A is atmospheric light or air light and t is the transmission map. The aim is to obtain *J* of a hazy image. The term *J(x)* and *t(x)* is the multiplicative deformity of the scene radians and *A (1-t(x))* is the additive deformity, air light means the amount of light that is scattered when reflected from the scene point.

When the atmosphere is uniform, the transmission map *t* is given as,

$$t(x) = e^{-\beta d(x)} \qquad (2.2)$$

Where β is the scattering coefficient of the atmosphere and d is the distance from the camera (capturing point) to the scene of point.

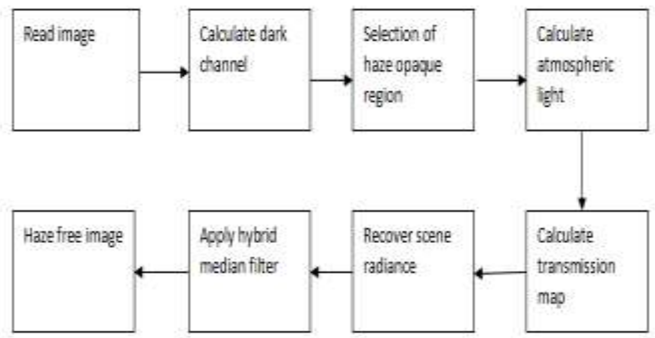


Fig 2: Block diagram of the proposed method

Fig 2 shows the block diagram. The method proposed to recover the haze free image is as follows:

2.1. Read the hazy image

To consider a image of a particular scene of point which contains dense haze, whose color contrast and quality is been degraded. The dark channel algorithm is applied for the same, in order to obtain a haze free image.

2.2. To calculate dark channel prior

The dark channel algorithm is considered for outdoor haze free images. In most of the non-sky regions the intensity of the pixels is very low or zero in atleast one color channel.

Conventionally, the dark channel of a hazy random image J is given by J^{dark},

$$J^{dark}(x) = \min_{\Omega(x)}\left(\min_{c\in\{r,g,b\}} J^c(y)\right) \quad (2.3)$$

Where J^c is a color channel of J and $\Omega(x)$ is the size of local patch centered at pixel x. The dark channel of a hazy image obtained is by eqn (2.3) the result of two minimum operators. These two minimum operators are independent of each other.

By observation, it can be inferred that most of the pixels of outdoor image possess very low intensity value or zero in J.

$$J^{dark} \to 0 \quad (2.4)$$

The low intensity in these dark channels is mainly due to three factors..., 1. Shadows of various objects like trees, rock etc....2. Colorful objects like flowers, water bodies etc....3. Black objects (object black by nature). The dark channel of a hazy image possesses higher intensity in the regions of dense haze, and lower intensity in the regions of lesser dense. This observation provides rough estimation about thickness of haze.

2.3. Selection of Haze Opaque Region

In order to estimate the atmospheric light, this causes the degradation of image with respect to color contrast and visibility. We first determine the Haze opaque regions, the regions which have nearly less or no haze, these regions provide the actual light reflected from scene of point because of no haze being present for attenuation or scattering, this involves human interaction for selecting the same. The top 0.1% of the brightest pixels are considered as haze opaque regions.

2.4. Atmospheric light Estimation

Haze attenuates the reflected light from the scene of point and some amount of atmospheric light is blended. Most haze opaque regions are considered as atmospheric light A. But the proposed method provides a much efficient way to estimate atmospheric light A with respect to each channel which accordingly increases the accuracy given by,

$$A_R = \frac{J^R - F_n}{\sqrt{F_d}} \quad (2.5)$$

$$A_G = \frac{J^G - F_n}{\sqrt{F_d}} \quad (2.6)$$

$$A_B = \frac{J^B - F_n}{\sqrt{F_d}} \quad (2.7)$$

Where, A_R is Atmospheric light of red color channel,

A_G Atmospheric light of green color channel.

A_B Atmospheric light of blue color channel.

F_n = filter (J_c, I_0)

F_d = filter ((J_c-F_n)2, I_0)

2.5. Transmission Map Estimation

Transmission map provides the amount of deformity in an image due to atmospheric light. If $t(x)$ is the amount of light which is not scattered and reaches the camera when a hazy image is captured. By normalizing the hazy eqn (2.1) as:

$$\frac{I_c(x)}{A_c} = t(x)\frac{J_c(x)}{A_c} + 1 - t(x) \qquad (2.8)$$

Where c represents color channel. The dark channel is calculated on both sides of eqn (2.8) by using minimum operators:

$$\min_{y\in\Omega(x)}\Big(\min_{c\in\{r,g,b\}}\frac{I_c(y)}{A_c}\Big) = \min_{y\in\Omega(x)}\Big(\min_{c\in\{r,g,b\}}t(y)\ \frac{I_c(y)}{A_c} + 1 - t(x) \qquad (2.9)$$

By dark channel prior algorithm, we have the approximation of eqn (2.3) using the same in eqn (2.9) the expression for transmission map is given as,

$$t(x) = 1 - \min_{y\in\Omega(x)}\Big(\min_{c\in\{r,g,b\}}\ \frac{I_c(y)}{A_c}\Big) \qquad (2.10)$$

In dark channel approximations the color of the sky is almost close to the color of the atmosphere, so *t(x)* tends to zero, which means that true transmission proves that the method could efficiently deal with both sky and non sky regions. In normal days the atmosphere possesses some amount of haze and is not haze free. So, when we completely remove haze from an image it loses its naturality, in order to preserve the same some amount of haze is retained in the final image.

$$t(x) = 1 - \omega \min_{y\in\Omega(x)}\Big(\min_{c\in\{r,g,b\}}\ \frac{I_c(y)}{A_c}\Big) \qquad (2.11)$$

ω Value lies in between 0 and 1. The value of ω is application based we fix it as 0.07 in the paper.

Patch size Ω(x) is one of the important parameters in the algorithm, it is estimated that larger the patch size the dark channel obtained is much better and is less precise for small patches. But by choosing larger patch sizes the final image obtained would be too saturated, so the patch size we consider here for estimation is 15*15.

2.6. Recover Scene Radiance.

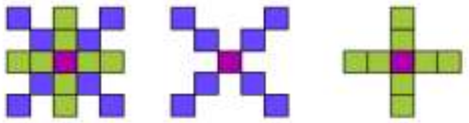
By the estimation of atmospheric light and the transmission map and substituting in eqn (2.1) we could obtain scene radiance, when true transmission occur the direct deformity term tends to zero. The final scene radiance is given as,

$$J(x) = \frac{I(x) - A}{\max\,(t(x), t_0)} + A \qquad (2.12)$$

The scene radiance obtained directly may possess noise so the lower bound of eqn is restricted to t_0.

2.7. Hybrid Median Filter

After the application of the scene radiance equation the haze free image is more prone to impulse noise. The noise occurred is due to transmission errors, storage problems etc. So, to eliminate this noise Median filters are used. Hybrid median filter is one of them which eliminates noise in much better way by considering neighboring pixels in both cross and plus format. Firstly, the pixels in cross neighborhood are considered and median of them is obtained and then the median of the pixels present in plus neighborhood are obtained. Now the filter compares two median values with the centre pixel and obtains the final median value.



(a) 5×5 neighbourhood (b) 45° neighbours (c) 90° neighbours

Fig 3. Cross and plus format of HFM

3. EXPERIMENTAL RESULTS

In this section a hazy image of size 1200*1200 is considered in fig (4), by the application of dark channel algorithm. The dark channel of the image in fig (5) provide rough estimation of haze. fig (6) helps in selection of haze opaque region for atmospheric light estimation. Fig (7) is the transmission map which explains the amount of light that reached camera without scattering. Fig (8) gives the haze free image and the complete haze free image after noise removal by hybrid median filter is given in fig (9).

Fig 4. Hazy arbitrary image

Fig 5. Dark Channel Image

Fig 6. Selection of Haze Opaque Region

Fig 7. Transmission map

Fig 8. Haze free image

Fig 8. HFM Image

By performing the necessary calculations, we try to estimate the visibility metric.

4. CONCULSION

This paper demonstrates the importance of dehazing an image. By the combination of Dark Channel Algorithm and Hazy Imaging Model, we obtain much sophisticated and efficient approach. The equation for atmospheric light provides much more realistic value for A and the visibility metric is found to be high due to this approach. Now for the image of size 1200*1200 the visibility metric obtained is 25.073.

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