Defogging Of An Image

Jinita Jose
Research Scholar, VLSI and Embedded System
St. Joseph's College of Engineering and Technology
Pala, India
Email id: jinitajosejej@gmail.com

***Abstract*— Outdoor imaging is plagued by poor visibility conditions. The observed objects lose visibility and contrast due to the presence of atmospheric haze, fog, and smoke. A major problem is spatially-varying reduction of contrast by stray radiance (air light), which is scattered by the haze particles towards the camera. In this paper the image is defogged using the dark channel prior method and its results are compared with the histogram equalization methods.**

Keywords- ***Image Defogging, Dark channel, Histogram equalization***

I. INTRODUCTION

Images of outdoor scenes are usually degraded by the particles and water droplets in the atmosphere. Haze, fog, smoke are such phenomena due to atmospheric absorption and scattering. The irradiance received by the camera from the scene point is attenuated along the line of sight. The incoming light is also blended with the air light, which means light reflected into the line of sight by atmospheric particles. The degraded images lose contrast and color fidelity. Since the amount of scattering depends on the distance of the scene points from the camera, the degradation is spatially variant.

The term single image defogging is used to describe any method that removes atmospheric scattering (e.g., fog) from a single image. In general, the process of removing fog from an image increases the contrast. Thus single image defogging is a special subset of contrast restoration techniques.

Fog is referred as the homogeneous scattering medium made up of molecules large enough to equally scatter all wavelengths. So the fog is evenly distributed and colourless. The process of removing fog from an image (defogging) requires knowledge of physical characteristics of the scene. One of these characteristics is the depth of the scene. This depth is measured from the camera sensor to the objects in the scene. If scene depth is known, then the problem of removing fog becomes much easier. Ideally, given a single image, two images are obtained: a scene depth image and a contrast restored image.

Narasimhan [1] addressed the problem of restoring the contrast of atmospherically degraded images and videos. Narasimhan's method estimates depth from two images of the same scene that are captured under different weather conditions. In spite of the improved defogging performance, this method cannot be used for dynamic scenes because of the requirement to capture multiple images of the same scene under different environmental conditions. Shwartz [2] exploited two or more images of the same scene having different degrees of polarization by rotating a polarizing filter attached to the camera. This method is very constrained in the image acquisition process, and cannot be used on existing image databases. Although existing methods addressed the possibility of enhancing foggy images, they are not suitable for consumer cameras because of the need of multiple images and special hardware devices. Fog removal method is similar to the contrast enhancement method. Kong [3] conducted histogram equalization over all image pixels concurrently.

In this paper, a novel prior—dark channel prior—for single image fog removal is discussed and compared with the histogram equalization method. The dark channel prior is based on the statistics of outdoor fog-free images. It is observed that in most of the local regions which do not cover the sky, some pixels (called dark pixels) very often have very low intensity in at least one colour (RGB) channel. In foggy images, the intensity of these dark pixels in that channel is mainly contributed by the air light. Therefore, these dark pixels can directly provide an accurate estimation of the fog transmission. By using the estimated air light and the transmission map the image can be defogged.

II. FOGGY IMAGE FORMATION MODEL

In computer vision and computer graphics, the model [4] widely used to describe the formation of a foggy image is

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

where I is the observed intensity, J is the scene radiance, A is the global atmospheric light, and t is the medium transmission describing the portion of the light that is not scattered and reaches camera.

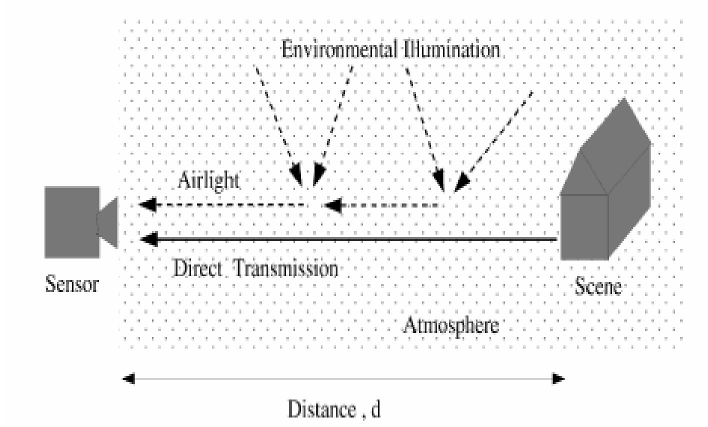

Figure 1.Foggy Image Formation Model

In Equation (1) the term J(x) t(x) on the right hand side is called direct attenuation, and the second term A(1-t(x)) is called air light. The direct attenuation describes the scene radiance and its decay in the medium, and the air light results from previously scattered light and leads to the shift of the scene colors. While the direct attenuation is a multiplicative distortion of the scene radiance, the air light is an additive one.

When the atmosphere is homogenous, the transmission t can be expressed as

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

where β is the scattering coefficient of the atmosphere and d is the scene depth. This equation indicates that the scene radiance is attenuated exponentially with the depth.

III. DARK CHANNEL METHOD

In fog free images, at least one of the color channel has some pixels whose intensity are very low and close to zero. Equivalently, the minimum intensity in such a patch is close to zero. The concept of dark channel [5] is like this. For an arbitrary image J, its dark channel J^{dark} is given by,

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

where J^c is a color channel of J and $\Omega(x)$ is a local patch centered at x. A dark channel is the outcome of two minimum operators $\min_{c \in \{r,g,b\}}$ is performed on each pixel and $\min_{y \in \Omega(x)}$ is a minimum filter. The minimum operators are commutative.Using the concept of dark channel, if J is an outdoor fog free image, except for the sky region, the intensity of J's dark channel is low and tends to zero:

$$J^{dark} \rightarrow 0 \qquad (4)$$

The low intensities in the dark channel are mainly due to three factors: a) shadows. *e.g*: the shadows of cars, buildings and the inside of windows in cityscape images, or the shadows of leaves, trees and rocks in landscape images b) colourful objects or surfaces. *e.g*: any object (for example, green grass/tree/plant, red or yellow flower/leaf, and blue water surface) lacking colour in any colour channel will result in low values in the dark channel c) dark objects or surfaces. *e.g*: dark tree trunk and stones. As the natural outdoor images are usually full of shadows and colourful, the dark channels of these images are really dark.

Due to the additive air light, a foggy image is brighter than its fog-free version in where the transmission t is low. So the dark channel of the foggy image will have higher intensity in regions with denser fog. Visually, the intensity of the dark channel is a rough approximation of the thickness of the fog. By using this property the transmission and the atmospheric light can be estimated.

Dark channel prior is partially inspired by the well known dark-object subtraction technique widely used in multispectral remote sensing systems. In this, spatially homogeneous fog is removed by subtracting a constant value corresponding to the darkest object in the scene.

A. *Estimating The Transmission*

First normalize the foggy image equation given in Equation (1) by A. That is each color channel is normalized independently.

$$(I^c(x) / A^c) = t(x) (J^c(x) / A^c) + 1 - t(x) \qquad (5)$$

Assume that the transmission in a local patch $\Omega(x)$ is constant. It is denoted as $\hat{t}(x)$. Then the dark channel is calculated on both sides of Equation (5). Equivalently, the minimum operators are put on both sides.

$$\min_{y \in \Omega(x)} (\min_c (I^c(y) / A^c)) = \hat{t}(x) \min_{y \in \Omega(x)} (\min_c (J^c(y) / A^c)) + 1- \hat{t}(x) \qquad (6)$$

Since $\hat{t}(x)$ is a constant in the patch, it can be put on the outside of the min operators.

As the scene radiance J is a fog free image, the dark channel of J is close to zero due to the dark channel prior.

$$J^{dark}(x) = \min_{y \in \Omega(x)} (\min_{c \in \{r,g,b\}} J^{c}(y)) = 0 \qquad (7)$$

As A^c is always positive, this leads to

$$\min_{y \in \Omega(x)} (\min_c (J^c(y) / A^c)) = 0 \qquad (8)$$

Putting Equation (8) in Equation (5), the multiplicative terms are eliminated and estimate the transmission $\hat{t}$ simply by

$$\hat{t}(x) = 1 - \min_{y \in \Omega(x)} \left(\min_c \left(I^c(y) / A^c\right)\right) \quad (9)$$

$\min_{y \in \Omega(x)} (\min_c (I^c(y) / A^c))$ is the dark channel of the normalized haze image $(I^c(y) / A^c)$. It directly provides the estimation of the transmission.

B. Estimating Atmospheric Light

The dark channel of a foggy image approximates the fog denseness. So the dark channel can be used to improve the atmospheric light estimation. First pick the top 0.1% brightest pixels in the dark channel. These pixels are most fog opaque. Among these pixels, the pixels with highest intensity in the input image I is selected as the atmospheric light.

C. Recovering Scene Radiance

With the atmospheric light and the transmission map, the scene radiance can be calculated using Equation (5). But the direct attenuation term J(x)t(x) can be very close to zero when the transmission t(x) is close to zero. The directly recovered scene radiance J is prone to noise. Therefore, transmission t(x) is restricted by a lower bound t_0 , that is a small amount of fog in very dense regions is preserved. The final scene radiance J(x) is recovered by

$$J(x) = ((I(x) – A) / \max(t(x),t_0)) + A \quad (10)$$

IV. HISTOGRAM EQUALIZATION

Histogram equalization [6] is a method in image processing of contrast adjustment using the image's histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values.

The method is useful in images with backgrounds and foregrounds that are both bright or both dark. In particular, the method can lead to better views of bone structure in x-ray images, and to better detail in photographs that are over or under-exposed. A key advantage of the method is that it is a fairly straightforward technique and an invertible operator. So in theory, if the histogram equalization function is known, then the original histogram can be recovered. The calculation is not computationally intensive. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal.

By using this method the images can be defogged by spreading the histogram equally so that all the intensity levels are represented equally. The image obtained has a washed out appearance due to the fact that all levels are emphasized, especially the brighter pixels and the darker pixels.

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V. SIMULATION RESULTS

The image is defogged using the dark channel and the histogram equalization methods. The platform used is Matlab and the simulation results are shown below.

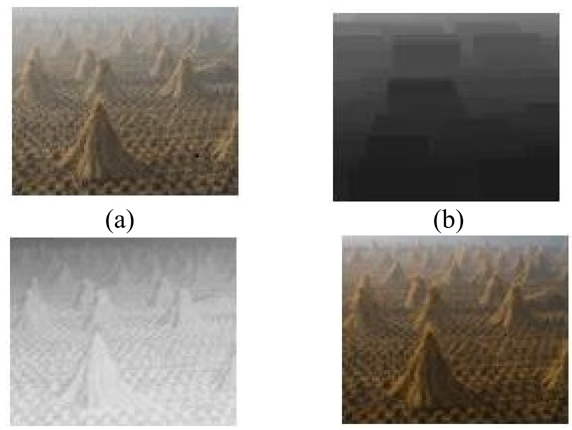

Figure 2. Using Dark Channel Method (a) Foggy Image, (b)Dark Channnel, (c) Transmission Map, (d) Defogged Image

Figure 3. Using Histogram Equailization Method
(a) Foggy Image, (b) Defogged Image

From the results, it is clear that the images obtained when histogram equalization applied to an foggy image contains information loss where as by using dark channel method better defogged image can be obtained.

VI. CONCLUSION

Images of outdoor scenes are usually degraded by the turbid medium (e.g., particles and water droplets) in the atmosphere. Haze, fog, and smoke are such phenomena due to atmospheric absorption and scattering. In this paper two methods for image defogging, dark channel and histogram equalization is discussed and the methods are simulated in Matlab. Dark channel method gives a better defogging.

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AUTHORS PROFILE

Jinita Jose receiced the B.Tech (Electronics and Communication Engineering) degree from St.Joseph's College of Engineering and Technology, Pala affilated to Mahatma Gandhi University, Kottayam in 2012, and presently she is doing M.Tech (VLSI and Embedded System) degree from St.Joseph's College of Engineering and Technology, Pala.