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Single Image Haze Removal Method for Inland River

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Abstract

Due to environmental pollution, the climate is worsening. The fog days up to 60% of the year in inland certain segments, which it has seriously affected the marine electronic cruise normal operation and navigation safety. According to the inland video image becomes gray and lack of visibility in foggy weather conditions, and in order to remove the haze to get a clear image color and contour, this paper presents a method based on Jones Extension Matrix and the Dark Channel Prior. First, we obtain the light intensity in the atmosphere and the estimated concentration of the haze by using Dark Channel Prior, and via using the Jones Extension Matrix and the parameters of Stokes' Law to eliminate part of the scattered light. At last, we have completed the function of image dehazing by brightness adjustment factor based on N pixels in the field of step brightness and improve the brightness based on Retinex Principle for the recovered image. Experimental results show this algorithm improves scenery visual effect in condition of haze. It is provided a clear video image for the marine electronic cruise in the foggy day.

Keywords: *Jones Extension Matrix, Stokes' Law, Dark Channel Prior, Retinex, Marine Electronic Cruise.*

1. Introduction

In the variety of modes of transportation, water transportation is one of the most important transportation, and the inland water transport is the most important component of water transport [1]. Due to environmental pollution, the climate is worsening. The fog days up to 60% of the year in inland certain segments [2], which it has seriously affected the marine electronic cruise normal operation and navigation safety. Although many of the science and technology workers carried out extensive research on the fog image clarity, and they have already achieved some success, but inland river fog image restoration problem is still one vacancy of the domestic and international research, becoming a major problem in the field of computer vision until now.

In recent years, more and more domestic and foreign research scholars are increasingly concerned about the atomization recovery of the degraded image, and they proposed a lot of fog algorithm. At recent, there are tow major categories dehazing methods including image enhancement and image restoration method. The image enhancement method can effectively improve the fog image contrast, outstanding image detail, to improve the visual effect of the image. Such as Rui Yibin [3] According to the Retinex theory and MSR algorithm, normal interception stretch of foggy image processing. And RUSSO F [4] using wavelet multi-scale analysis of the details of the fog in Figure equalization to fog. Method for image restoration through the establishment of the fog image degradation model inversion degradation process has been clear fog-free image, and its effect to fog method better than the image enhancement. Tan [5] by expanding the local contrast of the restored image to achieve the effect of fog. Fattal [6] assume that the propagation of light and scene target surface shading part is local and not related to the premise, it is estimated that out of the scene irradiance, and thus derive the transmissivity map to recover the image. He [7] found that the dark channel prior law to find the transmission rate to achieve the image to fog. The Li and Liu [8] based on the dark channel prior and the wavelet coefficients of correlation to determine the irregular region, and finally restored image map and irregular areas of the transmittance to obtain the desired fog effect.

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This paper is inspired and presents a new improved method to defog: According to the inland video image becomes gray and lack of visibility in foggy weather conditions, and in order to remove the haze to get a clear image color and contour, this paper presents a method based on Jones Extension Matrix and the Dark Channel Prior. First, we obtain the light intensity in the atmosphere and the estimated concentration of the haze by using Dark Channel Prior, and via using the Jones Extension Matrix and the parameters of Stokes' Law to eliminate part of the scattered light. At last, we have completed the function of image dehazing by brightness adjustment factor based on N pixels in the field of step brightness and improve the brightness based on Retinex Principle for the recovered image. The method is reasonable in physics, and it is even able to deal with target that is very far away from camera in heavy fog. Meanwhile, this method depends neither on two or more input images of different polarization directions, nor on the possibility that the light transmission function has larger variance or shadow exists on target surface. It can avoid halo effects by using the median operation.

2. Jones Extension Matrix

Polarization is a very important concept in physical optics, we can use various ways to describe polarized light and polarization devices, such as matrix method, the index function method and bond with the ball method, especially, the way to use the Jones matrix (Jones) and Mueller matrix (Mueller) represent the polarization devices has a very good effect. Jones matrix and Mueller matrix have both similarities and differences, the two matrix between the light waves superposition and the phase information of the operation is different, the former does not keep phase operation information, lighting waves of coherent superposition, while the latter keep phase operation information, coherent light waves of superposition, therefore we choose Mueller matrix to participate in eliminating the scattering operations. Jones matrix includes horizontal line up partial device, vertical line up partial device, + 45 □ lines up partial device, -45 □ lines up partial device, 1/4 wave plate (vertical fast axis), 1/4 wave plate (level fast axis), dextral rounded partial device and left-lateral rounded partial device, as is shown in table 1.

Table 1. Common Jones Matrix

Optical Component	***Jones matrix***	***Optical Component***	***Jones matrix***
Horizontal Polarizer	$\begin{vmatrix} 1 & 0 \\ 0 & 0 \end{vmatrix}$	1/4 Retardation Sheet (Vertical)	$\begin{vmatrix} 1 & 0 \\ 0 & i \end{vmatrix}$
Vertical Polarizer	$\begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix}$	1/4 Retardation Sheet(Horizontal)	$\begin{vmatrix} 1 & 0 \\ 0 & -i \end{vmatrix}$
$+45^{o}$ Polarizer	$\begin{vmatrix} 1 & 1 \\ 1 & 1 \end{vmatrix}$	Right-Handed Circle Rotation Polarizer	$\frac{1}{2}\begin{vmatrix} 1 & -i \\ i & 1 \end{vmatrix}$
-45^{o} Polarizer	$\begin{vmatrix} 1 & -1 \\ -1 & 1 \end{vmatrix}$	Left-Handed Circle Polarizer	$\frac{1}{2}\begin{vmatrix} 1 & i \\ -i & 1 \end{vmatrix}$

Due to the mist in the picture, white balance can be simplified as close to the average image. For some complex image, the color of the image changes, white balance is equal to image's local average approximately [9, 10]. To offset the scattering, this paper take up the horizontal and vertical polarizer in the matrix operations.

$$M_{\equiv} = \begin{vmatrix} 1 & 0 \\ 0 & 0 \end{vmatrix} \tag{1}$$

$$M_{\perp} = \begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix} \tag{2}$$

Equation (1) $M_{\equiv}$ means the horizontal polarization components, equation (2) $M_{\perp}$ means vertical polarization components, and expands the matrix effectively.

$$M_{\equiv} = \begin{vmatrix} 1 & -s \\ 0 & 0 \end{vmatrix} \tag{3}$$

$$M_{\perp} = \begin{vmatrix} 0 & 0 \\ -s & 1 \end{vmatrix} \tag{4}$$

In equation (3) and (4), s means scattering coefficient, and the value of it is decided by the scattering intensity, that is, by the atmosphere mist concentration, experiments showed that, s ranges from 0-0.1, distinguish level is less than 0.01. Stokes Law [11] (Stokes Law, 1845) can be applied to visible light intensity, if let natural light go through the polarized elements, its light intensity:

$$\mathrm{I} = \mathrm{I}_0 M \tag{5}$$

Among them, I_0 stands for the incident light intensity, while stands for the intensity of light after polarized.

Then $M_{\equiv}$ and $M_{\perp}$ are substituted into the equation (5), it will get the equation (6).

$$\begin{cases} I_{\equiv} = I_0 M_{\equiv} \\ I_{\perp} = I_0 M_{\perp} \end{cases} \tag{6}$$

3. The Dehazing Method Based on Jones Extension Matrix and Dark Channel Prior

3.1. Background

Research areas in the river to fog, only need to consider the transport properties of visible light in the atmosphere, researchers can ignore the light wave frequency. Such as figure 1. The light entering the camera includes two parts, one is the haze scattering formation I_S, and the other is direct exposure of the target object formation I_R [12].

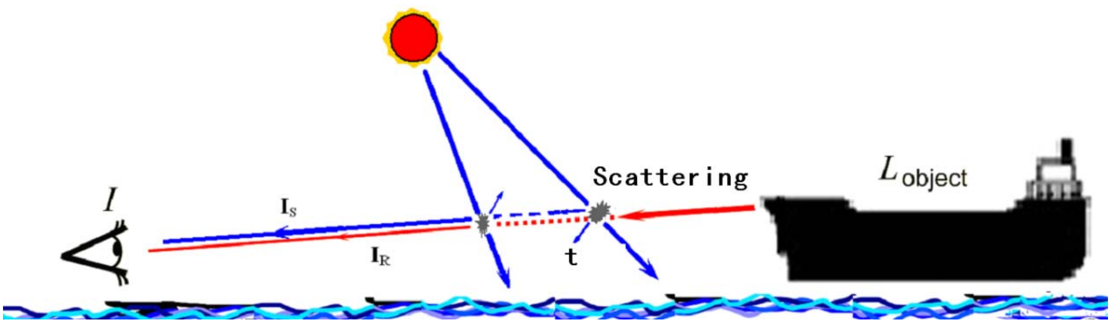


Figure 1. Inland River Foggy Image

In computer vision fields, the model widely used to describe the formation of a haze image is equation (7).

$$I(x) = L_{object} \cdot t(x) + A_{\infty}(1 - t(x)) \tag{7}$$

Where $I(x)$ is the light entering the camera, x is the distance of the camera and the object, L_{object} is the light of the target object formation, $t(x)$ is the atmosphere medium transmission describing the portion of the light that is not scattered and reaches the camera, and A_{∞} is the global atmospheric light. According to Figure 1, the equation (7) can be rewritten as equation (8).

$$I(x) = I_R(x) + I_S(x) \tag{8}$$

Where $I_R(x)$ is the reflected light of the target object formation, it is actually the object light intensity by the atmosphere (fog atmosphere) into the observed strength of the camera, $I_S(x)$ is the scattered light of the atmosphere. So we would get the equation (9).

$$I_R(x) = L_{object} \cdot t(x) \tag{9}$$

3.2. The Principle of Dehazing Method Based on Jones Extension Matrix and Dark Channel Prior

The principle of the algorithm shown in Figure 2, it would process the image by Jones Extension Matrix and Dark Channel Prior because of the inland foggy image characteristics. First, it could obtain the scattered light approximate strength by Jones Extension Matrix operations, and then calculate the reflected light intensity. Second, it could calculate the atmospheric optical transfer function according to the Dark Channel Prior, and then improve the brightness of the restored image; at last it would obtain the desired dehazing effect.

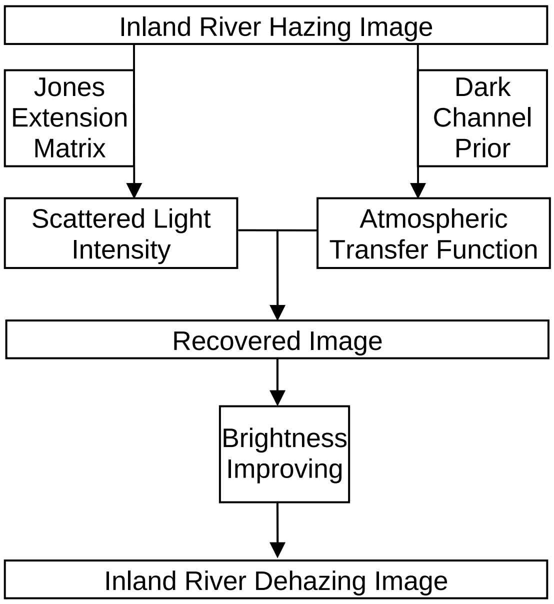


Figure 2. The Principle of Dehazing Method Based on Jones Extension Matrix and Dark Channel Prior

Equation (10) calculated by (6), (7) and (9), it could eliminate some of the scattered light and get a new image.

$$L_{object} \cdot t(x) \approx I(x)M_{\equiv} + I(x)M_{\perp} \tag{10}$$

Obviously, the intensity of light entering the direct irradiation of the target object can be expressed as equation (11).

$$L_{object} \approx \frac{I(x)M_{\equiv} + I(x)M_{\perp}}{t(x)} \tag{11}$$

Reference [7] gives the approximate equation of the atmospheric optical transfer function, such as the type (12) as shown.

$$t(x) = 1 - \min_{c}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \tag{12}$$

Actually, $\min_{c}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c}))$ is the dark channel of the original hazing image $\frac{I^c(y)}{A^c}$. It directly provides the estimation of the transmission function for atmospheric.

Because of the worsening of the global environment, even through in the sunny weather of meteorology sense, the air will always have some scattering particles. Therefore, when we observe the distance object, the haze will always exist, and influence people's visual habit. More importance is that the haze is an important clue to the [12, 13] that the human eyes judge depth of field. This phenomenon is called air perspective. Therefore, in order to meet people visual demand, the algorithm of this paper is not completely to dehaze, but selectively reserve a small amount of haze for distant scene, the dehazed image after this will look more natural. In equation (12) by introducing a constant type parameters, $\omega \in (0,1)$, the equation (12) can be rewritten for equation (13).

$$t(x) = 1 - \omega\min_{c}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \tag{13}$$

It is very similar between the brightness in the cross of the sky and the river distance and the atmospheric light. In this paper, it was taken in the experimental calculation of the estimates. In fact, the estimate is reliable because of the sky and the river crossover from the camera at infinity. So, the value of atmospheric optical transfer function $t(x)$ tends to 0. That is the equation (14).

$$t(x) = 1 - \min_{c}(\min_{y\in\Omega(x)}(\frac{I^c(y)}{A^c})) \to 0 \tag{14}$$

It would get $I^c \to A^c$.

3.3. Brightness Improving Based on Retinex

3.3.1. Background of Retinex

Retinex theory is proposed by the Land, who in the 1970s of the last century model based on the color and brightness of color constancy ideas objects, human visual perception to a point of light does not depend on the absolute light values, and the surroundinglight value is related to that human perception of the color of objects depends on the surface characteristics of the reflected light, and has nothing to do with the incident [14, 15]. The theory assumes that the light intensity of a image $I(x, y)$ by the reflection component $R(x, y)$ and the radiation component $S(x, y)$, such as equation (15).

$$I(x) = R(x, y)S(x, y) \quad (15)$$

The general process of the Retinex algorithm shown in Figure 3, then according to the different methods to estimate the brightness of the image to get a different enhancement.

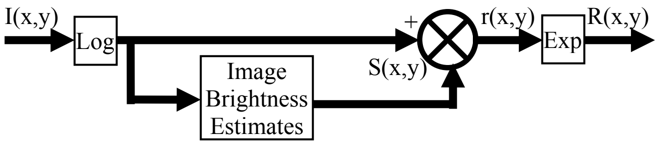


Figure 3. The General Process of Retinex Algorithm

It puts the logarithm operators on equation (15) both sides. And it can be obtained by equation (16).

$$\log I(x, y) = \log R(x, y) + \log S(x, y) \quad (16)$$

Let $\begin{cases} i(x,y) = \log I(x,y) \\ r(x,y) = \log R(x,y) \\ s(x,y) = \log S(x,y) \end{cases}$, then it can be obtained $i(x,y) = r(x,y) + s(x,y)$, at last it can be obtained equation (17).

$$r(x, y) = i(x, y) - s(x, y) \quad (17)$$

Let $G(x,y) = \lambda e^{\frac{x^2+y^2}{c^2}}$, and It puts the source image $I(x,y)$ smoothing filter operators and logarithm operators, then puts the result to $s(x,y)$ in equation (17), at last puts the antilog operators on the new equation (17) and get Single-Scale Retinex Algorithm [15]. Such as equation (18).

$$R^{'}(x, y) = \exp(i(x, y) - \log(S(x, y) * G(x, y))) \quad (18)$$

Where $R^{'}(x,y)$ is the enhanced reflection component, $G(x,y)$ is the core of Gauss, λ is the normalization constants, c is a constant to control the scale of the Gaussian filter range. Experiments show that c in $[80,100]$, the gray dynamic contrast enhanced to achieve better balance, there is no obvious halo effect.

3.3.2. V Enhanced for Restored Image

HSV color space, also known as HSB color space, relative RGB color space, a more accurate perception of color and brightness on the contact and remain in the calculation of simple, typically obtained inland fog images are converted from RGB space to HSV color space[16]. The V component is reflected in the brightness of the image information in the HSV space, its value determines the corresponding pixel shading to a reasonable range of enhanced, can improve the overall brightness of the image after the restore of the river fog image.

It gets the river fog image recover the results from equation (11) L_{object} converted from RGB space to HSV space, filtering with a Gaussian template of its V component. This paper introduces the function as the image brightness adjustment factor δ, the function step brightness of the pixel where V component of the N neighboring pixels to invade the brightness variations in different directions, as shown in Figure 3, which is equivalent to a neighborhood where pixels by pixels Gaussian filter window, the brightness adjustment factor such as equation (19) shows, then the Gaussian approved the re-defined as equation (20).

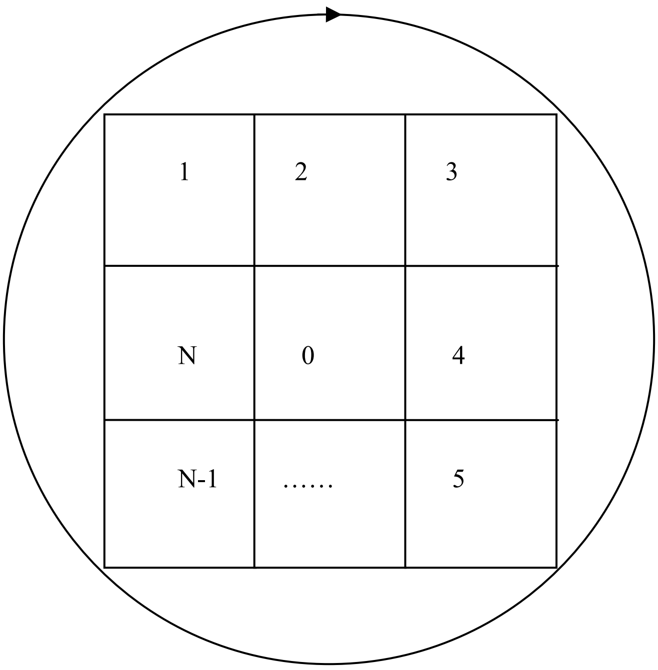


Figure 4. N Neighborhood Pixel Step Brightness Diagram

$$\delta = \sum_{i=1}^{N} \left| V_0 - V_i \right| \tag{19}$$

$$G(x,y) = k\delta e^{\frac{x^2+y^2}{c^2}} = k\sum_{i=1}^{N} \left| V_0 - V_i \right| e^{\frac{x^2+y^2}{c^2}} \tag{20}$$

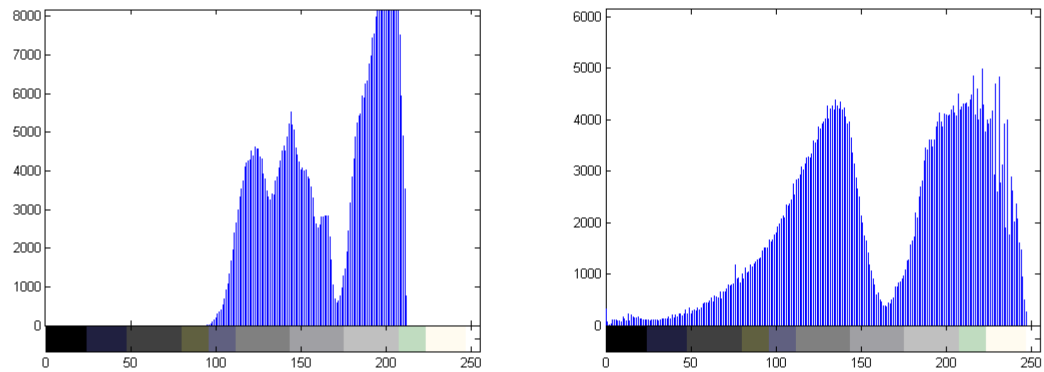
Where is a linear regulator, c is the scale factor, in this article experiments $k = 8$ and $c = 80$.

4. Experimental Result

It shoot a set of foggy experimental image using the Sony DSC-T5 digital camera in the Yangtze River Riparian. According to dehazing method proposed in this paper, the first combination of Jones Extension Matrix and Dark Channel Priori to defog, and then through the Retinex principle to improve the brightness, shown results in Figure 6. Where (a) is original source image, (b) is dehazing image. It compare the gray histogram of original source image and gray histogram of dehazing image, shown results in Figure 7. Where (a) is histogram of original source image, (b) is histogram of dehazing image. The gray histogram of original source image is between 150 and 200, apparently because of haze, and the goal of scene is hazy and white. The gray histogram of dehazing image is between 0 and 250, it get a clear structures and colors image, also accord with visual rule.

(a) (b)

Figure 5. Experimental Results



(a) (b)

Figure 6. Gray Histogram Comparison of Original Source and Dehazing Image

5. Conclusion

The purpose of this paper is to realize the image to dehaze, proposed a very simple but effective to dehaze algorithm for single inland foggy image. It improves the image brightness to dehazing image uses the N pixels in the field of step brightness as the brightness adjustment factor by Retinex principle. The experimental results this paper used a lot of hazy images in Yangtze River Riparian shows that, can make most dehazed effect of images more ideal, but cannot apply all the hazy images, such as image mutation in hazy area. This method is not suitable for real-time dehazing for video because of not running fast enough. Above the existing problems, in the next stage the author team will improve efficiency and study more perfect model to adapt to different environment hazy image.

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