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A Comprehensive Review of Single Image Defogging Techniques Used for Sea Fog Images

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ABSTRACT
Image Defogging is a well-addressed and challenging problem in the area of image processing. The foggy weather conditions in the atmosphere cause adverse effects on the images captured by the camera which in turn make it difficult to identify and detect the objects. Image defogging has many applications in the real world including traffic safety, remote sensing, agricultural monitoring, maritime surveillance, underwater imaging, etc. Based on these applications many defogging algorithms have been proposed in the past decades. Almost all defogging algorithms concentrate more on land images rather than ocean images. Fog removal from ocean images is more challenging than of removing fog from land images due to the atmospheric properties of fog in the sea. This paper mainly focuses on the study and review of various defogging approaches used for the removal of fog in ocean images. This work discusses some image-defogging techniques applied to ocean images, to get a clear vision of the images for various applications.

Keywords: Image defogging, image restoration, atmospheric scattering model, convex optimization

1. Introduction

Fog and haze are two different factors that adversely affect the images and both create many problems in image processing. The images acquired by a visual system are degraded due to the scattering of atmospheric particles under foggy weather conditions. The image degradation can affect the detection, tracking, recognition of objects, image analysis and limit the efficiency of the visual system. There were many papers addressing both these image defogging and image dehazing independently ie. either to remove fog or to remove haze in the image.

The contrast and visibility of ocean images may reduce due to the presence of fog seen in the images and there by affecting computer vision, makes the object features difficult to identify by human vision and image recognition tasks. Fog removal in ocean image is an important issue in computer vision applications. Due to high density of fog in ocean images, various image features may lost and unclear which in turn reduces the reliability of images for various purposes. Many image defogging algorithms were developed to remove fog from land images, based on atmospheric scattering model employ transmission map estimation. Images appear in ocean have specific characteristics compared to land because of multiple scattering effects. This study mainly focuses on the defogging methods in ocean images rather than land images.

Many single image defogging algorithms proposed recently can be categorized as image- enhancement methods, image- restoration based methods, image-fusion based methods, prior-based methods and learning – based methods etc. Image – enhancement methods use image processing techniques to improve the visual quality of the image. Image restoration based methods use an image degradation model to get the fog free image. Image-fusion based method produce a high quality image without using a physical model. Prior based method analyses the features of clear image to estimate the transmission map and atmospheric light intensity of haze image. Learning – based method use neural networks instead of depending on prior knowledge of image.

Image enhancement algorithm gives better defogging result by improving image contrast and image quality etc. Kim et al. [1] proposed a histogram equalization method to increase image contrast to get defogging images. Stark [2] proposed an adaptive image contrast enhancement method to improve the problem of poor local contrast based on histogram equalization method. A lot of Image enhancement algorithms were proposed include wavelet transform [3] and homomorphic filtering [4].

The image restoration algorithm introduces the prior knowledge obtained by observation, estimates the unknown variables in the physical model, and finally obtains the image without fog. Many image defogging algorithms proposed in recent years were based on atmospheric scattering model [5,6]. Tan [7] proposed an image defogging algorithm to maximize the local contrast of the image. . Fattal [8] proposed a method which in turn improve image visibility and restore the contrast in the fog- free image. Tarel et al. [9] proposed a defogging algorithm which can be applicable to gray and color images. He et al. [10] proposed a dehazing method based on dark channel prior (DCP) theory. DCP is based on the assumption that image patches have low intensity in at least one color channel. If the number of dark channels in the image is large then the value of these dark channels is very small or close to zero and on the basis of this findings, the haze-free image was restored. The dark channel prior (DCP) method can effectively solve the problem of image dehazing based on observations and assumptions. Zhu et al. [11] proposed a defogging method using color attenuation prior (CAP) for image defogging. In color attenuation prior model, a linear model for the scene depth is created based on the difference between brightness and saturation of the pixels within haze image. Based on this observation, this method models the scene depth and restores the information of scene depth.

In learning-based methods, convolutional neural networks are used to extract features. To avoid depending on prior knowledge, many defogging algorithms use convolutional neural networks instead of manually extracting features of fog, to remove fog from the image. For example, Ren et al. [12] proposed an image defogging method based on multi-scale convolutional neural network and estimated the transmission map. Here the atmospheric light and transmission map are estimated separately.

All the algorithms discussed above give good defogging performance on land images, but is does not improve the visibility and clarity of sea fog images. Sea fog images have large sky area and high fog density. The single atmospheric scattering model will not give a good performance in sea fog image defogging.

The paper is organized as follows. Section 2 describes atmospheric scattering model. Section 3 describes the comprehensive scattering model with multiple scattering effect .Section 4 describes the related works in this field for the removal of sea fog images. Section 5 gives the conclusion.

2. Atmospheric Scattering Model

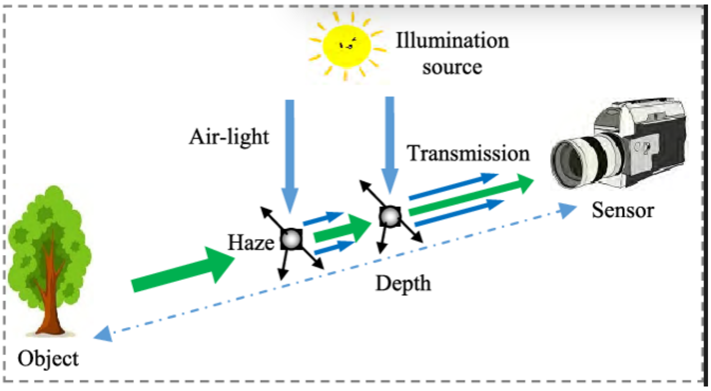

Figure.1. Atmospheric Scattering Model

The schematic diagram of Atmospheric Scattering Model is shown in figure 1. According to atmospheric scattering of light, an image consists of two components. First component is the attenuation of reflected light from the object to camera. The second component is the scattering of airlight reaching the camera. The image defogging model assumes that scattered light in the atmosphere is a linear combination of direct transmission and airligt. The image defogging model can be represented as

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

Where I(x) is the hazy image, J(x) is the haze free image, A is the global atmospheric light and t(x) is the medium transmission describing the portion of light that reaches the camera, The main goal of fog removal is to recover J(x) from I(x). In this model there are two unknown parameters, Atmospheric light A and t(x) is the transmission matrix defined as the following, with scattering coefficient "β" and distance between the object and the camera d(x).

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

For getting haze free image, first to estimate the uniform Atmospheric Light A and transmission t(x). From these two parameters we have to estimate the haze free image J(x). The idea behind this mathematical model is that airlight gets scattered by suspended particles in the air(haze) before reaching the lens of the camera. The amount of light actually captured depends on how much haze is present, which is reflected in β and also how far the object id from the camera, reflected in d(x).

3. Multiple Scattering Model

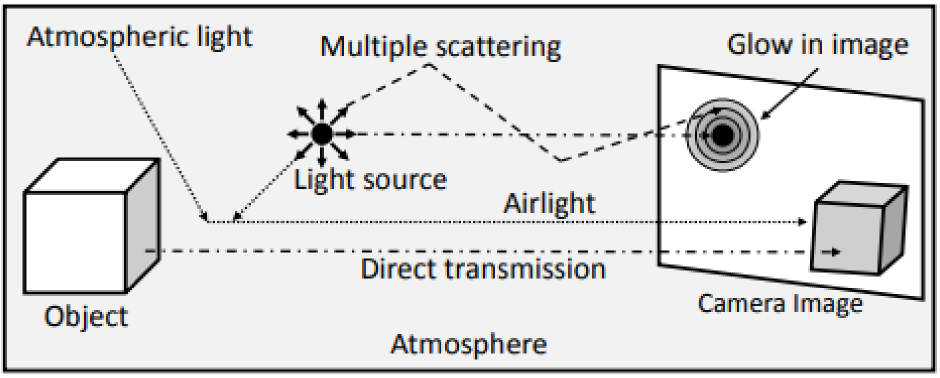

Figure. 2. Multiple Scattering Model [19]

4. Image Defogging Methods for Sea Fog Image

4.1 Fusion Based Defogging Approach

This is a simple, but effective fusion algorithm [15] used for removing fog from sea fog images based on fusion method. Based on Ancuti [14] fusion strategy, an image can enhance by the multi-scale fusion of two images derived from the original image. The main steps of this fusion strategy are two input images are generated by linear transformation and guided image filtering. The first input of fusion is obtained through linear transformation and is used to reduce noise also. The second input image of the fusion process is obtained through guided image filtering. The two input images are fuse by using a simple fusion method. Finally the defogged image is obtained by while balance process. Here the input images obtained from original image are able to enhance the visibility of the sea fog image. The flowchart of fusion based defogging approach is shown in figure 3.Image fusion technique have been used in various areas include remote sensing, medical, surveillance applications, vision enhancement etc.

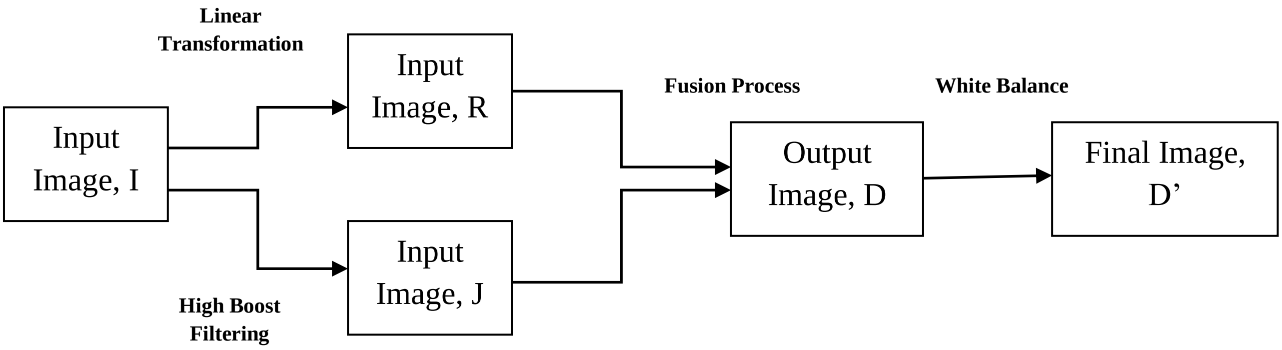

Figure 3. Flowchart – Effective Fusion Defogging Approach for single sea fog image

4.2 Sea fog removal network using multiple scattering model

An S in [16] proposes an end-to-end sea fog removal network based on multiple scattering model. The fog density of ocean images is more than that of land image, which is not handled by using single atmospheric scattering model. All the image defogging methods discussed in land images are based on atmospheric scattering model [17,18], and it does not consider multiple scattering effects. The effect of multiple scattering in ocean scene is considered by using multiple atmospheric scattering models.

In this method the multiple scattering model was reconstructed and the three parameters were fused into one parameter. Here the clean image with blur kernel was expressed as Hadamard product. In the end-to-end network sub pixel convolution method is used to remove halo artifacts and smooth dilation convolution method can be used to avoid gridding artifacts. For getting detail texture and structure information, multiple loss function including Mean Square Error loss, perceptual loss and multi-scale structural loss functions are used to optimize the network

The image under multiple scattering is represented by

$$\mathrm{J(x)} * \mathrm{k} = \frac{1}{t(x)} I(x) - A\frac{1}{t(x)} + A \qquad (3)$$

Under the influence of multiple scattering the image J(x) * k will appear halo and blur. The convolution of the clean image with the blur kernel is known as Hadamard product and equation (3) can be rewritten as

$$\mathrm{J(x)}.\mathrm{k} = \frac{1}{t(x)} I(x) - A\frac{1}{t(x)} + A. \qquad (4)$$

In the atmospheric multiple scattering model estimating three parameters separately will result in the accumulation of errors and estimation of blur kernel is more difficult. So in this method fused the three parameters into a single parameter K(x) and estimated only one parameter.

$$\mathrm{J(x)} = K(x)I(x) - K(x) + 1,$$

$$where\ K(x) = \frac{\frac{1}{t(x)}(\mathrm{I(x)-A})+(\mathrm{A-x})}{k(I(x)-1)} \qquad (5)$$

Three parameters were fused into one parameter based on the atmospheric multiple scattering model and the single parameter estimation will affect the dehazing effect. After this we make a deep network model that can learn the features and estimate the parameters accurately. This network model can input foggy images and output clear images. The network model consists of two modules such as K-estimation module to estimate the parameter and clean image generation module used to recover the defogging images

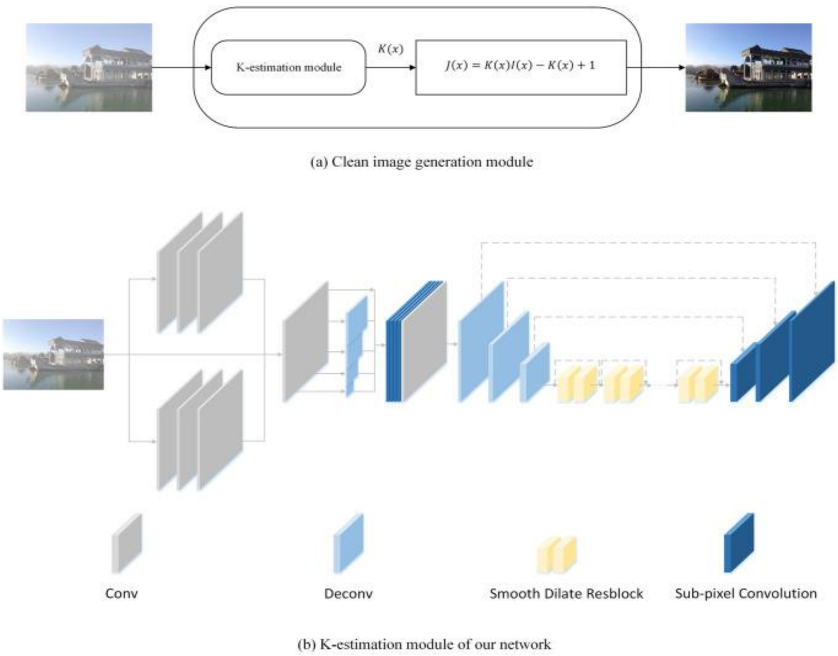

Figure 4. Sea fog removal network using multiple scattering model [16]

4.3 A Sea Fog Image Defogging Method Based on the Improved Convex Optimization Model

This is the sea fog removal algorithm proposed by Huang et al. [20] based on improved convex lens optimization and restore the images by using fewer prior conditions. Here an improved split-Bregman iterative method is used to obtain the transmittance and a clear image and the relationship between transmittance and a clear image is gathered without any prior conditions. An atmospheric light map is used to estimate the atmospheric light value by using a fusion method by simplified atmospheric light value and the Value channel in the hue–saturation–value (HSV) space.

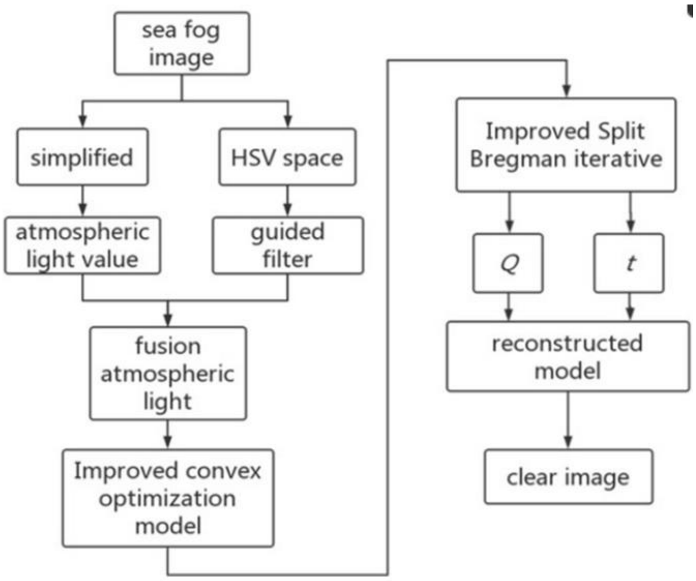

Figure 5. Sea fog removal network using multiple scattering model [20]

The steps of this flowchart are, at first calculate the atmospheric light value by using simplified atmospheric light value estimation method. The V channel combined with guided filtering is used to estimate fused atmospheric light estimation and an improved convex optimization model is constructed. By using split Bregman iteration to calculate the convex optimization model, the transmittance and a clear image was obtained.

5. CONCLUSION

This review paper provides a comprehensive survey of single image defogging methods used especially for sea fog image. Defogging methods have various applications in the area of marine engineering such as underwater imaging, maritime surveillance etc. This paper review some previous works related to remove fog from sea images. Among all these papers, no one completely consider the issues come in sea fog. No technique completely satisfies all issues. It has been observed that each paper is useful for handling particular issues in the image. All the discussed work has its own advantages and disadvantages.

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