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Instant haze removal from a single image

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Abstract

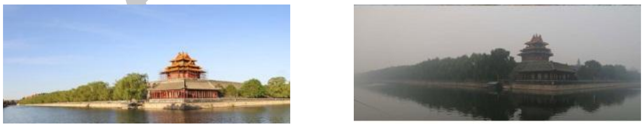
Images captured in bad weather are usually be degraded compared to those in clear days. For this, we draw on atmospheric optics and we propose a simple but powerful approach to remove haze from a single image based on imaging model under atmospheric scattering . For images with nearby objects under dense fog or distant objects under mild fog, we estimate the scene structure as transmission from the image model based on the optical irradiance characteristic which depends solely on its depth. Moreover, we present a reliable statistical principle for estimating global atmospheric light. Incorporating these two estimations into the haze imaging model, we can recover the contrast and color quality as well as that of a haze-free image. Experimental results on a variety of hazy images have shown the power of the methodology.

Key words: Bad weather; Single image; Haze removal; Atmospheric imaging model; Atmospheric optics; Transmission

1. Introduction

Virtually all acquisition of images or videos in computer vision system is based on premise that the observer is immersed in a transparent medium (air). In this condition (we call 'clear day'), light rays reflected by scene directly travel to the observer without any alteration. However vision sensors in outdoor applications work not only under 'clear ' day, but inevitably work under bad weather such as haze , fog, rain or snow etc. , which would alter the light rays energy and may lead the vision system work failure. A dependable vision system must allow for the entire spectrum of weather conditions. It is imperative that bad weather's influence must be removed prior to image analysis.

The study of interaction of light with atmosphere is known as atmospheric optics. Under bad weather, the irradiance reached the camera from the scene point is attenuated along the line of light as it travels through the atmosphere. Furthermore, the incoming light received by the camera is mixed with the airlight[11] (reflected into by atmospheric particles). In the presence of haze, the key optical characteristics of an image, such as intensity and color, are altered by the light's interactions with atmosphere. These interactions can be classified into three categories namely, scattering, absorption and emission. Of these, scattering due to atmospheric particles is the most pertinent. All these interactions result in degraded images. The degraded images suffer from lower contrast and biased color as shown in Fig. 1(b).



(a) (b)

Figure 1. Image of same scene under different weather. (a)Haze free image, (b) Haze image

Haze removal is to remove the haze from an image and improve the quality of the haze degraded image[5]. In analyzing and evaluating the effects of atmospheric on imaging, and in the study of interaction of light and medium, we need knowledge [15] from optical and physical disciplines, not just from images. The research on image dehazing is a crossing subject. It is a challenging problem in computer vision application and it started late.

Fortunately there has been significant progress recently in the haze removal. Many methods have been proposed and they can be divided into two classes, methods which use multiple images [1][5][7][8] [9]and those which use a single image[2][3][4]. In [9], a haze free image is used as a reference. More information[1][5][7][8] is obtained from multiple images of the same scene under different weather conditions.

Haze removal from a single image generally uses a strong prior or assumption. Additional information such as polarization information [3] and dark channel [2][4] are used to remove the haze. Tan[2] removes the haze by maximizing the local contrast of the input image with the prior that haze-free image must have higher contrast than that in the input hazy image. The result images are visually improved but halo effect probably happens at the region of depth changing. Fattal[3] gets the medium transmission based on estimating the albedo of the scene, under the assumption that the transmission and surface shading are locally uncorrelated. The performance of this approach depends on the estimation of input data's statistical characteristics. It may fail when the estimation is not accurately under bad weather.

Yitzhaky[18] use blind restoration (also named as blind deconvolution) to restore atmospherically degraded images. In [18], the best (closest to ideal) step-edges are automatically exacted from the degraded image to indentify PSF which is then used via a Wiener filtering to restore the image. It's efficient besides it's great computational load.

Kaiming He[6] accomplished the haze removal with a prior-dark channel[12][13]. Kaiming He's approach is physically effective and can produce great results. However, it has great computational cost due to the soft matting and may fail in the case that the assumption is broken or when attempting to handle heavy haze images. In [10], He improved the method by introducing guiding filter, replacing the soft matting, thereby decreasing the computation cost. However it is still has block effect since it is based on the dark channel.

In this paper, we propose a method estimating the medium transmission from the imaging model based on the hypothesis that airlight is the main cause of image irradiance under thick haze in the imaging mechanism. Additionally for its robust, we introduce a factor p to represent the airlight effect which allow us to get a smooth transmission image. We estimate the atmospheric light (generally as sky light) based on the fact that sky light is not the only intensity source of an image in the haze weather. By incorporating these two estimated results into a haze imaging model, we can produce a depth image and recover the clear image.

Our approach is physically and practically valid and is even able to handle distant objects in heavy haze image. But like any approach with assumption, our algorithm also has its own limitation. It may fail when the image suffers from extremely heavy haze. This weakness may be resolved by combining with the infrared ranging technique.

2. Model of haze imaging

Atmospheric scattering is a dichromatic procedure. The irradiance of sensor received is composed of two parts: object reflection and diffuse reflection of particles in atmosphere as shown in Fig.2.

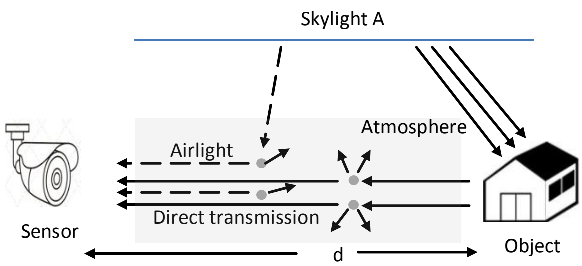


Figure 2. Atmosphere optical imaging model .

2.1 General formation of a haze image