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Real time image and video deweathering: The future prospects and possibilities

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ABSTRACT

The availability of extremely high computational power at an affordable cost is giving shape to many new computer vision challenges. The real-time deweathering of images/videos is one such challenge which may come true in near future. The intent of this paper is focused on real time deweathering of the images and videos that have been extensively researched and developed over the past few years. The present work initially describes the cause of image degradation under bad weather condition and it also describes various techniques used for deweathering of images by using image enhancement algorithms. All algorithms are analyzed in terms of their image quality enhancement and processing time based on extensive simulation results on same hardware platform. This study will thoroughly guide a researcher to work towards the development of the real-time deweathering system.

1. Introduction

Recent studies on a vision in a bad weather begin at the late 90s. Weather free vision is essential for outdoor surveillance system, vehicle driving, outdoor object recognition and many other requirements. Generally, bad weather conditions always affect the visibility of images. Under bad weather conditions, the contrast and color of the images are drastically degraded. To improve the contrast of weather degraded images generally used image processing methods are histogram equalization, unsharp masking and contrast stretching. But, the effects of weather cannot be completely removed by these techniques. In other words, it is simply not possible to expect consistent success without studying and modeling of the atmospheric conditions. So for deweathering of images it is essential to consider both of these methods (enhancement and physical methods) which can significantly remove the weather effects from the images.

Imaging in poor weather is often severely degraded by scattering due to suspended particles in the atmosphere such as haze and fog [1–3]. Based on the type of the visual effects, bad weather conditions are broadly classified into two categories: steady and dynamic. In steady bad weather, constituent droplets are very small (1–10 μm) steadily float in the air. Fog, mist, and haze are examples of steady weather. The intensity produced at a pixel is due to the aggregate effect of the large numbers of the droplets within the pixel's solid angle. In dynamic bad weather, constituent droplets are 1000 times larger (0.1–10 mm) than those of the steady weather. Rain and snow represent dynamic weather conditions. As the image quality degradation dependents on size of suspended particle, the image restoration methods and algorithms also differ for steady weather condition and dynamic weather condition.

In this paper, we focus on image restoration techniques in steady weather condition. In Section 2, the scattering mechanism, which degrades the image is discussed. Based on the scattering mechanism, the optical model which acts as the basis of the development of image restoration algorithms is discussed in Section 3. In Section 4, existing deweathering algorithms for images and videos are discussed. The seven important real time deweathering algorithms are summarized in Section 5. Among them, the best four approaches are extensively simulated and then compared based on simulation results in Section 6. Finally the concluding remark is given in Section 7. This article will guide a researcher to understand clearly and easily the various deweathering algorithms and their advantages as well as disadvantages. Based on this study, one can chose to work for improvement of deweathering algorithms for better quality or to improve the speed of algorithms for real time applications.

2. Atmospheric scattering mechanisms

Atmospheric scattering is the cause of image degradation in bad weather condition. It is the redirection of electromagnetic energy by particles suspended in the atmosphere or by large molecules

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0030-4026/

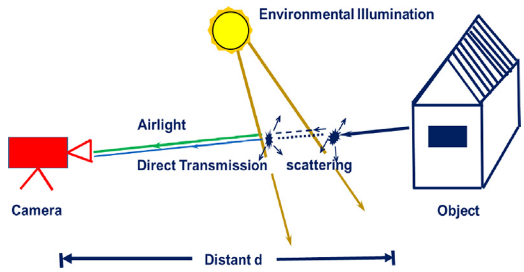

Fig. 1. The pictorial description of the optical model.

of atmospheric gases. Poor weather caused by atmospheric particles, such as fog, haze, etc., may significantly reduce the visibility and distort the colors of the scene. In general, the exact nature of scattering is highly complex and depends on the types, orientation, size and distributions of particles constituting the media, as well as wavelengths, polarization states, and directions of the incident light. In this section we summarize two models of atmospheric scattering i.e. attenuation and airlight, followed by the discussion on wavelength dependency of scattering [1].

2.1. Attenuation and airlight

The pictorial description of the optical model describing image capturing in the presence of atmospheric particles is shown in Fig. 1. Here, the reflected light beam coming straight from an object point to the camera is called direct transmission (or direct light). The reflected light beam coming from an object point, gets attenuated due to scattering by atmospheric particles. The attenuation model describes the way light gets attenuated as it traverses from an object point to the camera. This phenomenon is termed as attenuation, which reduces contrast in the scene. As shown in Fig. 1, small amount of light coming from the environmental illumination is scattered by the atmospheric particles, and coming toward camera. This leads to the change in color of the object. This phenomenon is termed as airlight. The image taken with the camera depends both on attenuation and airlight. The environmental illumination can have several light sources, including, direct sunlight and light reflected from the ground, etc. In steady bad weather conditions, attenuation is represented as:

$$I_{att}(x, y) = I_o(x, y)e^{-\beta d(x,y)} \tag{1}$$

where $I_{att}(x, y)$ is the attenuated image intensity at pixel (x, y) in presence of fog. $I_o(x, y)$ is the image intensity in absence of fog. β is the scattering coefficient and d is the distance of the object from the viewer or camera. Airlight is represented as:

$$A(x, y) = I_\infty(1 - e^{-\beta d(x,y)}) \tag{2}$$

where I_∞ is the global atmospheric constant.

2.2. Wavelength dependence of scattering

Due to the atmospheric particle, different wavelengths of light are scattered differently. The blueness of the sky and the bluish haze of distant mountains are examples of the wavelength selective behavior of atmospheric scattering [4,5]. Over the visible spectrum, Rayleighs law of atmospheric scattering provides the relationship between the scattering coefficient β and the wavelength λ as [6]:

$$\beta(\lambda) \propto \frac{1}{\lambda^\alpha} \tag{3}$$

where α is a constant varies between 0 and 4 depending on the exact particle size distribution in the atmosphere. For fog, $\alpha \approx 0$; all wavelengths are scattered equally and we see grayish (or white) fog. A wide gamut of atmospheric conditions arises from aerosols whose particle sizes range between minute air molecules (10^{-4} µm) and large fog droplets (1–10 µm) [3].

3. Optical model

The optical model usually used in dealing with bad weather, particularly in computer vision, is described as:

$$I(x, y) = \underbrace{I_o(x, y)e^{-\beta d(x,y)}}_{\text{Attenuation}} + \underbrace{I_\infty(1 - e^{-\beta d(x,y)})}_{\text{Airlight}} \tag{4}$$

The first term is the direct attenuation, and the second term is the airlight. Eq. (4) is in principle based on the Lambert–Beer law for transparent objects, which states that light travels through a material will be absorbed or attenuated exponentially [2]. When the atmosphere is homogenous, the transmission of the reflected light, which is determined by the distance between the object point and the camera is called as transmission map and can be expressed as:

$$T(x, y) = e^{-\beta d(x,y)} \tag{5}$$

Hence, an optical model equation can be described as:

$$I(x, y) = I_o(x, y)T(x, y) + I_\infty(1 - T(x, y)) \tag{6}$$

4. Deweathering algorithms

Deweathering algorithms can be broadly classified into two categories based on the approach they use to restore the image. Fig. 2 shows the classification of image restoration techniques. One is based on image enhancement technique, without considering the cause of degradation. This uses only image processing algorithms. The other set of algorithm considers the physical phenomenon of cause of image degradation due to bad weather. This uses the optical model which is discussed in the previous section to predict the pattern of image degradation and restore image. In this section all important deweathering algorithms belonging to both non-model based and model based techniques are analysed. These two techniques are discussed in this paper for better understanding of real time processing which is the combination of both techniques.

4.1. Non-model-based techniques

The most commonly used non-model-based techniques are histogram equalization, gamma correction and unsharp masking methods. Histogram equalization is an image enhancement process that attempts to spread out the most frequent intensity in an image. This is one of the most commonly used non-model-based technique which is applied directly on the weather degraded images to enhance the image quality by equally distributed pixel values [7–10]. The histogram equalization of color images is performed separately for red, green and blue (RGB) color channel. But this leads to undesirable change in hue. So, first convert the image to the hue, saturation and intensity (HSI) because hue represents most dominant color as perceived by an observer. Then apply histogram equalization to the intensity component only [11]. This is one of the method for improving the contrast of the weather degraded images. Other method is Gamma Correction (GC) method. Most imaging system produces values which are proportional to intensity. Sometimes, these values are not proportional to intensity and are subjected to a nonlinear transfer function. Gamma Correction (GC) is a process of compensating the nonlinearity in order to achieve correct reproduction of relative luminance [7]. These two methods are used for enhancement of the contrast. But, if we want to improve the enhancement of the contrast and sharpness of an image, we need a method for sharpness enhancement. This method name is unsharp masking. Some researchers had noticed that when