

Removal of Atmospheric Particles in Poor Visibility Outdoor Images

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Abstract

The visibility of a scene is degraded by weather phenomena such as rain drizzle, fog and haze. The degradation of image scene is due the substantial presence of particles in the atmosphere that scatter and absorb light. As the light spreads from object to the observer, the color and intensity is changed by the atmospheric particles. In this research, we suggest new methods to precisely detect airlight and correctly estimate the atmospheric veil from image that captured in bad weather. The result of suggested methods will be used in scattering atmospheric model to remove atmospheric particles namely, rain drizzle, fog and haze from a single image. Therefore a higher visibility image will be produced.

Keywords: atmospheric particles; airlight; scattering atmospheric model

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1. Introduction

The images captured in outdoor scenes are usually degraded by the turbid medium in the atmosphere. Bad weather such as fog and haze reduce the visibility and color fidelity, and the particles in atmosphere cause absorption and scattering. The irradiance received by the camera from the scene point is attenuated along the line of sight. Furthermore, the incoming light is blended with the airlight [1] (ambient light reflected into the line of sight by atmospheric particles). The degraded images lose the contrast and color fidelity of the scene. In addition, the amount of degradation depends on the distances of the scene points from the camera.

Removing rain drizzle, fog and haze can significantly increase the visibility of the scene and correct the color shift caused by the airlight. Moreover, rain drizzle, fog and haze removal is critical for a wide range of image-related applications, such as surveillance systems, intelligent vehicles, satellite imaging, and outdoor object recognition systems.

Bad visibility in poor weather is the most important problem for different applications of computer vision. Most automatic systems for monitoring, intelligent vehicles, outdoor object recognition, assume that the input images have clear visibility [2]. Unfortunately, this does not happen all the time, therefore improving visibility is an inevitable task.

In computer vision, the atmospheric scattering model is usually used to describe the formation of a foggy or hazy image. Almost all established methods are based on this model [3]. Reference [4] restores contrast of image scene by using two or more images taken in uniform bad weather. However, this method requires changing weather conditions to capture the images that will be used in contrast restoration. A method proposed by [5] uses the polarization approach to enhance the visibility. It is based on the fact that the scattered of airlight by suspended atmospheric particles is partially polarized. In this method, two images or more are taken through a polarizer at different orientations. The captured images are analyzed, taking into account the effects of the polarization of atmospheric scattering. This process will be inverted to recover the image from the effect of haze. Polarization-based approach requires two or more images; it is not sufficient to be applied in dense fog or haze weather.

Another method proposed by [6] recovers the scene of single image by using additional information provided interactivity by user. The user provides additional input such as approximately direction of scene depth, or a good region of color fidelity. This method requires additional information from user. Also the result will be varied based on the area that will be chosen by the user. Reference [7] uses 3D- geometrical model to determine the depth of the scene and recover scene albedo. It requires an interactive registration process to align the

image with geometric models of the world such as terrain or buildings. By registering the image to these models, depth becomes available at each pixel. However, the main disadvantage of this approach is unavailability of 3D model for all image locations.

Generally, all previous methods required additional information to recover scene albedo. In practical applications, it is difficult to use these techniques, so such approaches are restricted. New enhancement visibility methods are able to recover scene albedo by making various assumptions about airlight or colors in the scene.

In this research we suggest a new method to estimate the direct attenuation and airlight. The proposed technique will be used to restore the visibility of the image that is to remove the atmospheric particles. There are three steps involved: detecting the sets of white area to estimate the skylight, using two-step of estimations to inference the atmospheric veil, and recovering the image by using the previous estimations in atmospheric scattering model.

2. Background

In computer vision the atmospheric scattering model is widely used to describe the formation of a fog and haze image as follows [3]:

$$I(x) = Ap(x) e^{-\beta d(x)} + A(1 - e^{-\beta d(x)}) \quad (1)$$

Where $I(x)$ is the observed image intensity, A is the global atmospheric light (skylight), and $p(x)$ is scene albedo, $d(x)$ is a scene depth and β is the scattering coefficient of the atmosphere. The first term $Ap(x) e^{-\beta d(x)}$ on the right hand of the Equation (1) is called direct attenuation, and the second term $A(1 - e^{-\beta d(x)})$ is called airlight. To recover fog and haze from attenuation and infidelity color, we need to find the value of A , β , and $d(x)$ in (1).

Recent work on single image to recover scene albedo imposes limitations upon either the airlight or direct attenuation, or on both. Tan method [2] is based on two basic observations: first, the images that captured in clear-day have more contrast (enhanced visibility) than the image captured in bad weather; second, the airlight in image scene is variance and primarily depend on distance between the object and the viewer. Generally, there are two disadvantage of this method, First, it doesn't fully recover the scene's original colors or albedo, it is just enhance the contrast of an input image; second, it doesn't know the actual value of airlight, so the output image tend to have larger saturation than those in clear day images.

Fattal [8] relies on the assumption that the transmission and surface shading are locally uncorrelated. He estimates the optical transmission in hazy single image. Base on this estimation, the scattered light is removed to enhance the visibility of the scene and recover the low contrast in the input image. However, performance of this method greatly depends on the quality of the input data. On the other words, this method requires significant information (variance) in colors of the input image to work completely.

Tarel and Huati [9] present fast algorithm to recover scene albedo for single input image. They assume the small object in foggy or hazy weather has low saturation color. This method based on median filter. It is also propose new filter to preserve edge and corner to enhance the visibility restoration. This method assumes that the atmospheric veil must be smoothing all the time, and this assumption will maximize the atmospheric veil of the image.

He et al [10] presents simple and effective method to remove the fog from single image. They depend on kind of statistics of outdoor images that is free of haze. Result of these statistics is the most local patches in haze-free outdoor images contain some pixels (called "dark pixels") which have very low intensity in at least one color channel. According to this method, the intensity of these dark pixels in that channel is mainly contributed by the airlight. Therefore, these dark pixels can directly provide accurate estimation of the haze's transmission. Using this prior information with the haze imaging model, they recover input image from effect of haze and produce a good depth map. However, this method is invalid when the scene object inherently similar to the atmospheric light over a large local region and no shadow is cast on the object.

The method proposed in [3] assumes that the recovered image scene albedo has higher color contrast and the depth map tends to be all most smooth except along edges with large depth jumps. It performs white balance and simplifies the scattering atmospheric model to remove the fog and enhance the visibility for single image. In this method, the atmospheric veil

infers by using two steps. First, define the roughly estimation of the atmospheric veil by using minimal component of the color-corrected image. Second, refine the coarser estimate of atmospheric veil by using weighted least squares (WLS) optimization framework [11]. This method refines the coarse atmospheric veil based on WLS smoothing. This refining causes some distortion in estimation of the atmospheric veil.

The existing literature shows that there are still problems in detection of airlight, and there is no precise inference to the atmospheric veil that can help to recover the scene albedo correctly and to remove fog impact from the single image. In order to address the above mentioned problems, we develop a new technique to estimate airlight and direct attenuation to recover the scene from the effect of rain drizzle, fog and haze.

3. Research Methodology

In order to address the problem of the removal of rain drizzle, fog and haze from single image and achieve the research objectives, a systematic methodology phases are defined as shown in Figure 1

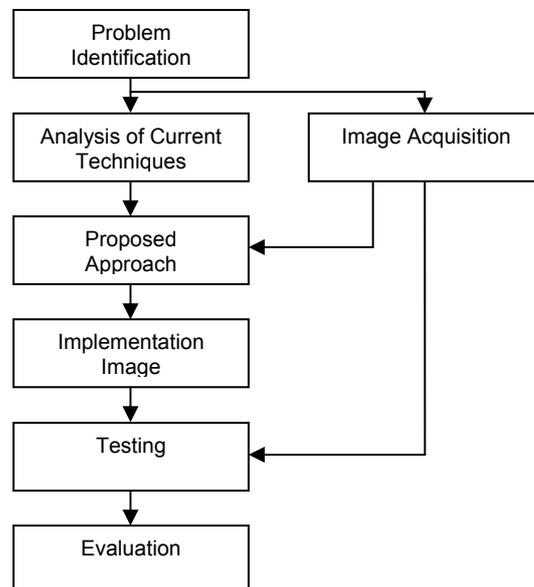


Figure 1. Research Methodology

3.1. Problem Identification

In this phase, the problem of the removal of rain drizzle, fog and haze is investigated in order to improve the visibility of rain drizzly, foggy and hazy images by addressing the problem of low contrast and color infidelity.

3.2. Image Acquisition

In this phase, we will use experimental set-up camera to obtain the rain drizzly, foggy and hazy images from different locations and with various levels of visibility in order to apply the proposed methods to remove the effect of poor weather. The captured images will provide input to the suggested system and the system will process the images to improve the visibility.

3.3. Analysis of Current Techniques

In this phase, the current methods and techniques related with image enhancement are to be investigated by focusing on scattering atmospheric approaches. By examining the current literature, this phase aims to identify the limitation of the existing methods in order to address these limitations in the proposed method.

3.4. Proposed Approach

As a result of investigating the existing methods and techniques examined in the previous phase, this phase aims to propose methods to address the restrictions in existing methods and particularly to meet the aim and objectives of the research.

3.5. Implementation

This phase will implement the proposed methods mentioned in previous phase by using object oriented programming language such as Java. To meet the aim and objectives of the research, different algorithms will be implemented to remove the rain drizzle, fog and haze effects and enhance the visibility of image.

3.6. Testing

In this phase we will test the performance of the suggested system. The testing of the system will be based on quality of output image. Based on such testing, the system will be further improved if the output images will not be producing the satisfactory results.

3.7. Evaluation

In this phase, the results of the suggested methods are to be evaluated compared to the existing methods in order to examine the quality of output image. To achieve the evaluation, two different methods will be used as follows:

3.7.1. Qualitative Method

the human perception method will be used to compare among the input image, output image, and the image captured in clear weather for the same scene. In this method we will use different images with different levels of visibility to exam the quality of images based on human perception. To achieve this method, few numbers of users will be invited to examine the quality of the output image and write their notes on the questionnaires that distributed to them for this purpose.

3.7.2. Statistical method

In this method, we will use a histogram to evaluate the images before and after visibility enhancement. The suggested method will be also compared with the established methods (i.e., Gray World and Histogram Equalization) as well as the latest research methods.

4. Visibility Enhancement

To remove rain drizzle, fog and haze from input image, we use atmospheric scattering model. Our proposed method consists of three steps: estimation of the value of skylight A , inference atmospheric veil from observed image $I(x)$, and use the output of previous steps to recover scene albedo $p(x)$ of the input image. These steps are defined as shown in Figure 2

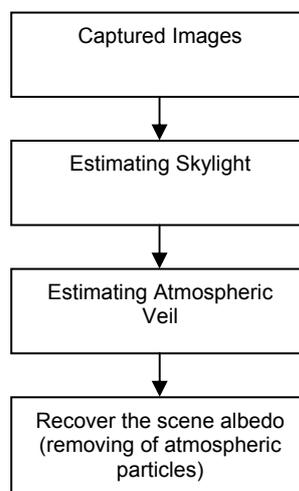


Figure 2. Visibility Enhancement Steps

4.1. Estimating Skylight

Most of previous study estimates the skylight A from high intensity pixel in the image. But this approach is inaccurate, because the high intensity pixel may not be the skylight, but rather the color of an object in the scene. To solve this problem, we suggest a three-step algorithm to find the skylight A . First, detect all the pixel sets of high intensity area in whole image. Second, calculate the variance of the contrast in each set. Third, choose the high intensity pixel to be skylight value A from the set that have low values of contrast.

4.2. Estimating Atmospheric Veil

The particles in the atmosphere (medium transmission) attenuate the scene radiance. The attenuation exponentially increases with depth of scene $d(x)$. In other words, the medium transmission $t(x)$ can be expressed by exponent attenuation. We can simplify the description as the following:

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

Another effect of atmosphere particles is the addition of an atmosphere veil $V(x)$. The atmosphere veil $V(x)$ can be expressed by the following:

$$V(x) = 1 - t(x) \quad (3)$$

According to He et al [1], to estimate atmospheric veil, we choose the minimum value for each pixel from all color channels. This process will be roughly estimating for atmospheric veil, expressed as following:

$$V(x) = \min I(x) \quad (4)$$

$$x \in \{r, g, b\}$$

In any outdoor images, the levels of contrast among the pixels give us a good knowledge of deep scene. In other words, the contrast level is a vital factor to keep the reality of the outdoor scene. Upon this factor, we propose a new algorithm to enhance the previous roughly estimation. This algorithm classifies roughly atmospheric veil to number of classes that equals the number of contrast level in origin image. This operation precisely estimates the real homogenous atmospheric veil.

4.3. Recover the Scene Albedo

During the previous step we obtained the atmospheric veil $V(x)$; from this value we can calculate medium transmission $t(x)$ upon (3):

$$t(x) = 1 - V(x) \quad (5)$$

Now we can simplify the scattering model in (1) to be as following:

$$I(x) = Ap(x)t(x) + AV(x) \quad (6)$$

The values we obtained from two previous estimations allow us to recover the scene albedo by using the following equation that is derived from (6):

$$p(x) = (I(x) - AV(x))/(At(x)) \quad (7)$$

5. Implementation

To implement the suggested methods and remove the effects of suspended particles in bad weather we will perform the following steps:

5.1. Acquire Image in Bad Weather

We will use mounted experimental camera with high resolution colors to capture images in bad weather conditions. This image will be the input images for our suggested system.

5.2. Acquire Image in Clear Weather

After performing step A, the mounted camera will be in the same location and same position till the bad weather conditions change and turn into clear weather conditions and this it may takes few hours. Then another image will be taken and this is the target image. This image will be used in the testing step.

5.3. Pair Images for All Weather Phenomenon

In this step, A and B steps will be used to capture the pair of the images for each weather phenomenon such as fog, haze, mist, and drizzle rain. One image is captured in bad weather (low color contrast) and another image is captured in clear weather conditions (high color contrast).

5.4. Different Background

In many previous methods which enhance the visibility of the image that has been captured in bad weather conditions, the result may not be correct when the scene objects are similar to the airlight and no shadow is cast on them. To make sure that the proposed methods will solve this problem, pair of images in different locations and different backgrounds will be captured to compare the output images with clear day images in the testing step.

5.5. Different levels of visibility

Some enhancement methods do not work in low level visibility such as dense fog. To make sure that the proposed methods will work in variety levels of visibility, the pair of images will be taken in different levels of visibility such as mist (light fog), medium and dense fog to compare the output image with clear day images in the testing step.

5.6. Applying the suggested methods

After the database of images has been created with different type of images that has been captured in different conditions, backgrounds and level of visibilities, the estimating skylight and atmospheric veil methods will be applied to remove the effects of suspended particles from input images and will produce higher quality images.

To evaluate our suggested methods, we will apply two main tests. First, the output images of suggested system will be visually compared with the images that were captured in clear weather conditions (target images). Second, the quality of output images will be statistically compared with input images; it will also be compared with results of the latest research methods.

6. Expected Result

The output images should be primarily similar to the images that are captured in a clear day. In other words, after applying the proposed method, the input images that are affected by bad weather conditions will be similar to the quality of clear weather images, In addition, the effects of suspended atmospheric particles will be removed from the output image. Furthermore, higher quality output images with high contrast and fidelity colors will be produced.

7. Conclusion

Enhancing any outdoor images that are captured in bad weather is based on two main factors, airlight and direct attenuation. The correct prior assumptions to estimate these two factors are the clue for recovering scene albedo from effects of suspended particles by using the scattering atmospheric model.

In this research, two prior assumptions were suggested in order to remove the effect of atmospheric particles from outdoor images. First, skylight value can be detected from the pixels set that have high intensity and low variance color contrast. Second, the precise estimation of

the real homogenous atmospheric veil depends on the classification of rough atmospheric veil into a number of levels that equal the number of color contrast in the input image.

To implement these two prior assumptions, the skylight detection method has been proposed to calculate airlight. We also suggest the homogenous atmospheric veil method to calculate direct attenuation.

The results of suggested methods will be used in the scattering atmospheric model to recover scene albedo and remove atmospheric particles, namely rain drizzly, foggy and hazy effects and obtain the true colors image.

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