Enhancement of Hazy Image Using Visibility Restoration Technique

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Abstract:***The visibility of outdoor images captured in inclement weather is often degraded due to the presence of haze, fog, sandstorms and so on. Poor visibility caused by atmospheric phenomena in turn causes failure in computer vision applications, such as obstacle detection systems, outdoor object recognition systems, and intelligent transportation systems and video surveillance systems. In order to solve this problem, visibility restoration techniques have been developed and play an important role in many computer vision applications that operate in various weather conditions. However, removing haze from a single image with a complex structure and color distortion is a difficult task for visibility restoration techniques. This paper proposes a novel visibility restoration method that uses a combination of three major modules: A depth estimation (DE) module, A color analysis (CA) module, and A visibility restoration (VR) module. The proposed depth estimation module takes advantage of the median filter technique and adopts adaptive gamma correction technique. By doing so, halo effects can be avoided in images with complex structures and effective transmission map estimation can be achieved. The proposed color analysis module is based on the gray world assumption and analyzes the color characteristics of the input hazy image. Subsequently, the visibility restoration module uses the adjusted transmission map and the color-correlated information to repair the color distortion in variable scenes captured during inclement weather conditions. The experimental results demonstrate that our proposed method provides superior haze removal in comparison to the previous method through qualitative and quantitative evaluations of different scenes captured during various weather conditions.***

Keywords: Hazy image, Bad weather, Depth estimation, Color analysis, Visibility restoration

1. Introduction

The sources of difficulties when processing outdoor images is the presence of haze, fog which fades the colors and reduces the contrast of the observed objects. Numerous visibility restoration approaches have been proposed to restore the visibility of degraded images inorder to improve system performance during inclement weather conditions. These visibility restoration approaches can be further divided into 3 categories.

- Additional information approaches
- Multiple image approaches
- Single-image approaches

In additional information approaches restore hazy images by using given scene depth information obtained from either additional operations orinteractions, such as through user operation to control position of the camera via a given approximation 3-D geometrical model. However, these approaches J. Kopf et al[10] are not well suited for real world assumption due to limitations placed on the acquisition of scene depth information by unknown geography information and additional user operation.

Multiple image approachesSchechner et.al [8] adopt two or more images of the same scene, which are captured by using specific hardware, example; a rotating polarizing filter, to effectively construct the scene depth information and further achieve visibility restoration of incoming hazy images. Unfortunately, the use of these multiple image approaches usually requires either excessive hardware expense or special devices.

Recently, many studies have focused on single-image approaches to restore the visibility of a hazy image. These approaches are based on either strong assumptions or priors by which haze thickness is estimated by using only a single image. Tan [2] proposed a method that restores hazy images via a single-input image by maximizing the local contrast of the image based on an observation that haze-free images possess higher contrast than input hazy images. This method can produce acceptable results, yet restored images may contain some block artifacts near depth discontinuities.

2. Literature Survey

The scene depth information of the degraded image is an important clue to haze removal. Many methods extract depth information from multiple images and extra information. For instance, binary scattering model is used to extract scene information from color images under different weather conditions [1]. In recent years, many researchers focus on achieving haze removal results from a single degraded image. Through statistics, Tan [2] found that clear images had higher contrast compared with foggy images, thus he maximized the local contrast of the restored image for enhancing image visibility. The disadvantage was that the color ofthe restored image was often too saturated. Based on the assumption that the propagation of light and shading parts of the target surface were locally uncorrelated, Fattal [5] first estimated the scene radiance and then derived the transmission image. As this method required sufficient color information, thus it could not process gray level images.

Narasimhan et.al [3] addressed the problem of restoring the contrast of atmospherically degraded images and video. The methods to locate depth discontinuities and to compute structure of a scene, from two images captured under various weather conditions. Using either depth segmentation ie, regions within closed contours of depth edges or scene structure, then showed how to restore contrast from any image of the scene taken in bad weather. Although structure computation requires changes in weather, the contrast restoration algorithm do not. The entire analysis is presented for monochrome images. However, this method can be applied to image captured using multispectral cameras, and the usual broadband RGB and gray scale cameras.

Xu et.al[4] proposes dominant haze removal algorithm dark channel prior and improve the algorithm by replacing the time consuming soft matting part with fast bilateral filter to get higher efficiency. Moreover this analysis the reason why traditional algorithm leads to dim image after haze removal and propose improved transmission rate formula inorder to get better visual effects of the image after dehazing. On this basis taking into account that the dark channel prior rule is not suitable for sky area, here decide to process this region with weaker method to improve the adaptability of the algorithm.

Fang et al [6] have discussed a new fast haze removal algorithm from multiple images in uniform bad weather conditions is proposed which bases on the atmospheric scattering model. The basic idea is to establish an over determined system by forming the hazy images and matchingimages taken in clear days so that the transmission and global air light can be acquired. The transmission and global airlight solved from the equations are applied to the local hazy area. This algorithm reduces haze effectively and achieves accurate restoration.

3. Existing System

Haze removal techniques belonging to the multiple image approaches category employ two or more images to estimate scene depth and subsequently remove haze formation. Schechner et al. proposed a method which uses two or more images of the same scene with different polarization degrees produced by rotation of a polarizing filter to compute scene depth and recover the vivid color of captured images. Methods proposed by Narasimhan et al.estimate scene depth and then remove haze by comparing two images that are captured under different weather conditions. However, the above haze removal methods using multiple images usually require additional expense or hardware in order to perform effectively.

Recently, research has focused on single image haze removal techniques which use strong assumptions or priors. Tan proposed a method which restores hazy images via a single input image by maximizing the local contrast of the image based on an observation that haze-free images possess higher contrast than input hazy images. This method can produce acceptable results, yet restored images may contain some block artifacts near depth discontinuities. The approach of fatal removes the haze by estimating the albedo of a scene and deducing the transmission medium from a single input image based on the assumption that transmission and surface shading are locally uncorrelated. However, this method may fail when input images contain dense haze. He et al. proposed a method which uses a key assumption that most local patches for outdoor haze-free images exhibit very low intensity in at least one of color channel, which can be used to directly estimate haze density and recover vivid colors.

4. Input Haze Image

The haze should be present in the input image in order to restore the haze free image. If haze free image is given as input image to the proposed visibility approach the estimated image might be in distorted form. The formation of haze in the captured image explained as follows.The optical model has widely used in the computer vision research field, particulary to describe the formation of hazy images captured by digital cameras. It is based on the physical properties of light transmission through atmospheric conditions.

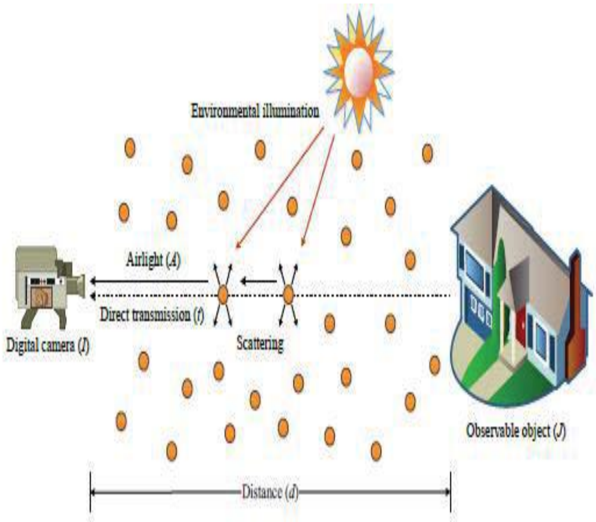

Figure 1: Pictorial description of the formation of hazy images in the optical model.

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

Where I (x) is the intensity of the observed hazy image, J (x) is the scene radiance, A is the global atmospheric light, and t (x) is the medium transmission representing the portion of light, which is not scattered and subsequently is received by the camera. The first term J (x)t(x) is called the direct attenuation; the second term A(1−t (x)) is called airlight. The optical model can be described by direct attenuation and airlight. Direct attenuation describes the decay of scene radiance and is dependent upon medium and scene depth, while airlight represents the scattering of light that leads to color shifts in the scene. A hazy image is formed when there are problems with light absorption and scattering by atmospheric particles between the digital camera and the objects being captured. This situation can arise due to inclement weather, such as haze, fog, sandstorms, and so on. If the atmosphere is assumed to be homogenous, and then the transmission t (x) can be expressed as

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

Whereβ is the scattering coefficient of the atmosphere and d(x) is the scene depth between the digital camera and the captured objects for each pixel x in the image.

5. Proposed System

A novel visibility restoration approach is proposed in order to restore hazy images captured during inclement weather conditions, such as haze, fog, sandstorms, and so on. This approach along with the atmospheric light estimation involves additional three modules: a Depth Estimation (DE) module, a Color Analysis (CA) module and a Visibility Restoration (VR) module.

Initially, the proposed DE module designs an effective refined transmission procedure that takes advantage of the median filter to preserve edge information and thereby avoid generation of block artifacts in the restored image. This is followed by a transmission enhancement procedure, which adjusts the intensity of the transmission map to achieve optimum haze removal results. After these two procedures are accomplished by the DE module, effective depth information can be obtained. Next, in order to recover true color, the color characteristics and color information of the input hazy image are, respectively, analyzed and acquired in the proposed CA module. Finally, the VR module recovers a high-quality haze-free image using the depth and color-correlated information to adequately conceal the atmospheric particles present in various real-world weather conditions.

Atmospheric Light Estimation

For estimation of the atmospheric light A in the outdoor image, the brightest 0.1% of pixels are chosen from within the dark channel prior. From among these, the pixels with the highest intensity in the input image are determined to be the atmospheric light A.

5.1 Depth Estimation Module

Depth estimation module is based primarily on the dark channel prior technique and is used to directly estimate the transmission map of a hazy image. However, as was mentioned here, two prominent problems exist in regard to the dark channel prior technique: generation of halo effects and insufficient transmission map estimation. The DE module circumvents these problems using a refined transmission procedure and an enhanced transmission procedure.

Refined Transmission

Because the primary operation of the dark channel prior depends on the minimum filter, the transmission map will usually experience a loss of edge information when estimation occurs. A refined transmission procedure that uses a median filter technique to preserve edge information of input hazy images and thereby avoid generation of halo effects. The median filter technique performs a nonlinear filtering operation that can effectively suppress impulsive noise components while preserve edge information. Now the refined transmission $t_{vr}(x)$ can be obtained as:

$$t_{vr}(x) = t^{p}(x) - VR(x)$$

Where $t^{p}(x)$ is the transmission and $VR(x)$ is the corrected atmospheric veil with detailed edge information.

Enhanced Transmission

The dark channel prior depends on the minimum value of the RGB channel and always produces an insufficient transmission map for images captured during sandstorm conditions. This is because the intensity value will be lower for at least one RGB channel in sandstorm images. In order to achieve optimum haze removal results, apply an adaptive gamma correction technique to adjust the intensity of the transmission map during this procedure. The enhanced transmission $et_{small}(x)$ is formulated using adaptive gamma correction as

$$et_{small}(x) = (X_{max})(t_{vr}(x)/X_{max})^{\gamma}$$

$$\gamma = \begin{cases} 1 + (\frac{t}{X_{max}}) & if\, t \geq T \\ 1 & if\, t < T \end{cases}$$

Where X_{max} represents the maximum intensity of the input, t_{vr} represents the intensity of refined transmission, γ refers to the varying adaptive parameter, t refers to the intensity value when cdf is equal to 0.1 and T is the adaptive threshold value set to 120. This technique also avoids artifact produced by equalization of gamma correction.

5.2 Color Analysis Module

During sandstorm conditions, captured images usually exhibit serious color distortion problems due to the fact that particular portions of the color spectrum are largely absorbed by atmospheric particles. He et al. propose an algorithm with which to recover original scene radiance. However, it uses the same restoration equation for each color channel, thus resulting in recovered images with serious color distortion problem. To solve this problem color analysis module is used which uses the gray world assumption to determine whether or not the average intensities of the each color channel are equal. The average intensities of the red, green, and blue channels are calculated by

$$avg_{col} = \frac{\sum_{i=1}^{M} I^{col}(i,j)}{MN}$$

where col ∈ {r, g, b}, MN is the size of observed image pixel. The color difference value is calculated by using the average intensity of each color channel.

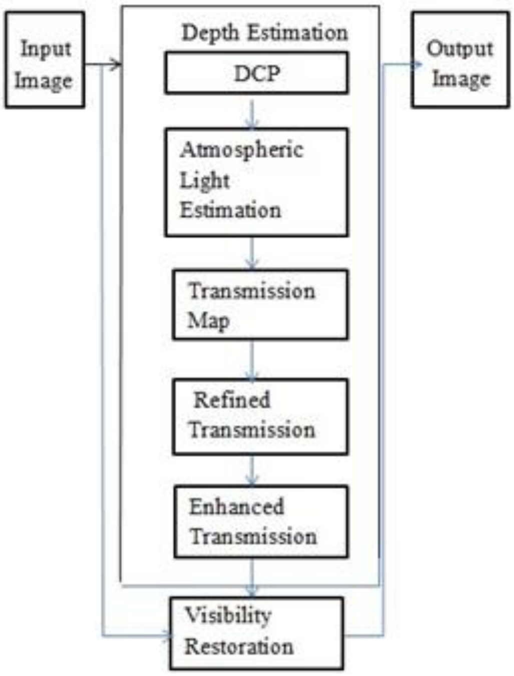

Figure 2: Context diagram of visibility restoration

5.3 Visibility Restoration

The proposed visibility restoration module uses the adjusted transmission map and the color-correlated information produced respectively by the depth information and color analysis module to recover high quality haze free image. The experimental results produced by both the methods were evaluated by qualitative and quantitative comparisons of images of several realistic scenes with varied weather conditions and features. These analyses illustrate the efficiency of this proposed visibility restoration approach. Not only can effectively circumvent significant problems regarding color distortion and complex structure, but it can also produce high quality, haze free images more effectively than the existing method. At last, the result obtained from AD and CA module is used to calculate the final enhanced visibility restoration frame as follows:

$$J^{col} = \frac{I^{col}(x) - (A^{col} - d^{col})}{ET} + (A^{col} - d^{col})$$

whereJ^{col} is the haze free frame, ET represents enhanced transmission. The frames obtained from hazy videos are turned to clear haze free frames and then by combining all those frames we get the final haze free video as the end result.

6. Simulation Results

The proposed technique has been evaluated in MATLAB R2013a. In our experiment images captured in varied real world weather condition with which to compare the results of each haze removal method. Based on these average restoration rates it is apparent that the proposed method is more effective than the dark channel prior based methods in varied real world environments.

Figure 3: Input image

Figure 4: Output image

7. Conclusion

In this paper, we propose a novel visibility restoration approach for images captured using improved depth estimation and color analysis. The proposed approach uses a combination of three main modules. a depth estimation module, a color analysis module and a visibility restoration module. First, the proposed depth estimation module applies a refined transmission procedure to avoid generation of block artifacts in the restored image by using median filter to preserve edge information of the image. Subsequently, an effective transmission map is estimated by adjusting its intensity via an enhanced transmission procedure based on the adaptive gamma correction technique. Next, the proposed color analysis module uses the the gray world assumption to analyze the color characteristics of the input haze image. The obtained color information can be adapted for various weather conditions including haze, fog, and sandstorms. Finally, the visibility restoration module can effectively restore the visibility of input images and obtain high-quality, haze-free results via the depth estimation module and the color analysis module. The experimental results produced by both methods were evaluated by qualitative and quantitative comparisons of images of several realistic scenes with varied weather conditions and features. These analyses illustrate the efficiency of our proposed visibility restoration approach. Not only can it effectively circumvent significant problems regarding color distortion and complex structure, but it can also produce high quality, haze-free images more effectively than in the previous method.

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