



A Review on Deweathering Methods: Fog & Haze Removal

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ABSTRACT

Image has important applications in many fields such as video surveillance, marine surveillance, traffic monitoring, border security, target identification and so on. In poor weather condition, fog removal from an image is an unavoidable problem. This paper presents a review on the different existing fog & haze removal techniques. Haze & fog brings trouble to many applications as it blemishes the visibility of the outdoor images. It is formed due to the two fundamental phenomena that are direct attenuation and the air light. Attenuation reduces the contrast of the image and air light increases the whiteness in the image. Haze & fog removal techniques reduces the whiteness, recover the color and contrast of the image. These methods are widely used in many applications such as outdoor surveillance, object identification, consumer electronics, traffic monitoring, border controls, marine surveillance, video security etc. The overall objective of this paper is to explore the various defogging methods for efficiently removing the haze & fog from digital images.

Keywords: Guided filter, Transmission map, Contrast enhancement, DCP, Air light, Attenuation.

1. INTRODUCTION

Bad weather condition such as fog, haze, mist, dust, rain, snow and smoke degrade the quality of the outdoor images. It is an annoying problem to photographers as it changes the colors & reduces the contrast of daily outdoor photos, it diminishes the visibility of the scenes and it is a threat to the reliability of many applications like outdoor surveillance, object detection, border security, and traffic monitoring. So removing haze from images is a broadly demanded area in computer vision and image processing.

The structure of this paper is as follows. In this paper, we try to elaborate existing image dehazing methods including the application characteristics, dehazing performance, complexity of algorithm and other aspects. The remainder of this paper is organized as follows. Section 2 discusses the taxonomy of image defogging techniques. Section 3 & 4 focuses on the methodology of defogging algorithms & briefly explores the advantages and disadvantages corresponding with each different method. Section 5 concludes this paper.

1.1 HAZE MODEL

Haze formation model is widely used in image processing. Haze model is used for the formation of image in the presence of bad atmospheric conditions. Image quality is degraded due to the presence of large number of substantial particles in the atmosphere which have significant size between 1-10 μm . The light coming from a camera is absorbed & scattered by these atmospheric particles. Fog is the combination of Airlight and Direct attenuation. This invisibility is due to two fundamental phenomena: Direct attenuation and Airlight describe as follow:

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

Where,

$I(x)$ = observed intensity of the x^{th} pixel,

$J(x)$ = scene radiance,

A = atmospheric light,

t = transmission medium describing the portion of the light unscattered and reaches direct to the camera.

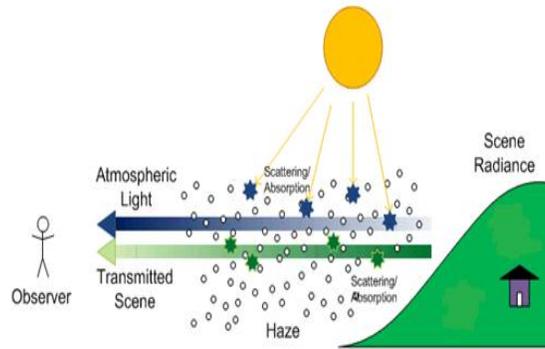


Figure1. Haze Model

In equation (1) first term, $J(x)*t(x)$ is called the direct attenuation, it explains how the scene radiance is attenuated in the medium. The second term, $A*(1-t(x))$ is called Airlight, it is the scattered light which cannot reach the camera, and may cause the shift of the scene color. Therefore, the estimation of atmospheric light A and transmission t is the key step which affects the restoration of foggy image.

2. TAXONOMY OF IMAGE DEFOGGING TECHNIQUES

The methods which have been proposed for fog removal from images can be roughly divided into two distinct categories in terms of whether a physical model is used or not as follows:

- 1) image restoration based on the physical model
- 2) image enhancement

Based on which processing pipeline is adopted:

(1) The first class algorithm recovers image based on the work flow which includes a sequence of processing steps such as building image degradation model, estimating image information and improving image quality, respectively.

(2) On the other hand, the second class algorithm deals with foggy image based on the feature information which comes from the low image brightness and contrast regardless of the reason of image degradation

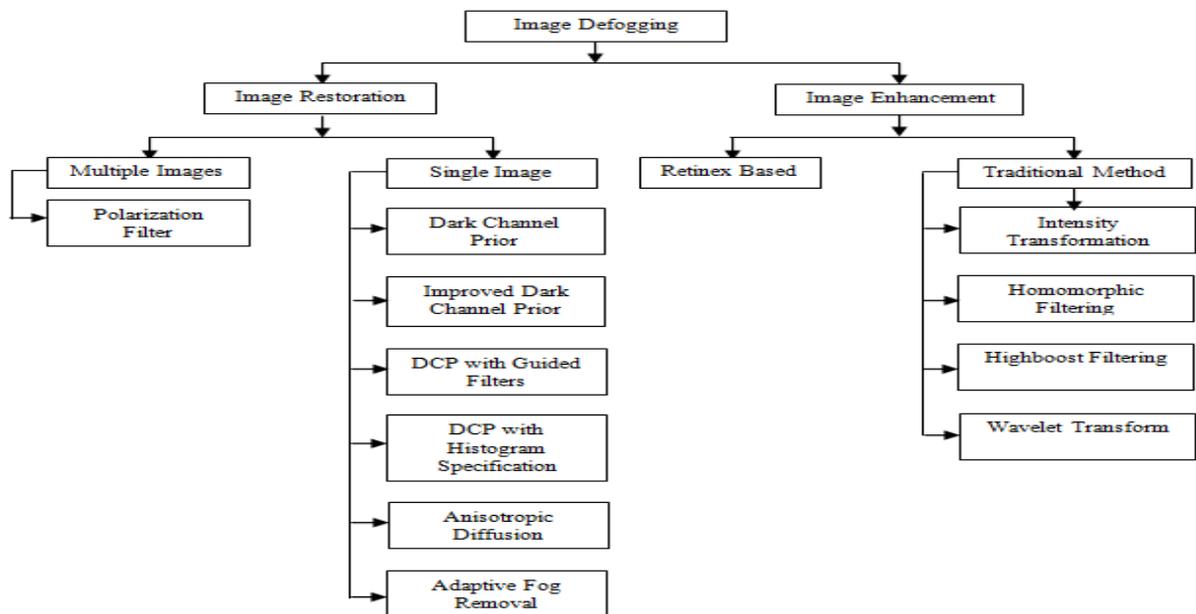


Figure2. Taxonomy of Image Defogging Techniques

3. DEFOGGING METHODS

Images photographed in hazy or foggy conditions capture the scene correctly as the observer sees it. But there are applications like the landing system of aeroplane or intelligent car driving systems where it is important to identify & see the objects that are obscured in the haze or fog due to bad weather conditions. For the fog & haze removal from images different methods are described below along with their strong points & weak points.

3.1 MULTIPLE IMAGES METHOD

3.1.1 POLARIZATION FILTER[1]

Multiple images can be used with the help of polarization filter to remove haze & fog. This method takes multiple images of the same scene that has been taken during different bad weather conditions as input. It is based on the fact that usually airlight scattered by atmospheric particles is partially polarized. The polarization filtering alone cannot remove the fog effects, except in restricted situations from images. This method, however, works under a wide range of atmospheric and viewing conditions. We analyze the image formation process, taking into account polarization effects of atmospheric scattering. Input image is combination of two unknown components. The first one is the scene radiance in the absence of the fog and the other one is Airlight. This method works instantly, without relying on changes of weather conditions

STRONG POINTS:

- Fog is removed with the help of polarization filter.
- There are no Halo artifacts in the resultant image.

WEAK PIONTS:

- This method requires multiple images of same scene under different weather conditions.



Figure3. Hazy Image[1]



Figure4. Haze Free Image[1]

3.2 SINGLE IMAGE METHODS[2]

3.2.1 DARK CHANNEL PRIOR

Dark channel prior is basically used for single image dehazing method. The DCP is based on the property of “dark pixels,” which have a very low intensity in at least one color channel, except for the sky region. Owing to its effectiveness in dehazing, the majority of recent dehazing techniques have adopted the DCP. The DCP-based dehazing techniques are composed of four major steps:

- 1) Estimation of atmospheric light.
- 2) Estimation of transmission map
- 3) Refinement of transmission map
- 4) Image reconstruction.

STRONG POINTS:

- Single image is required.
- Transmission map is estimated accurately.

WEAK POINTS:

- For Airlight estimation, assumption is made that only 0.1% brightest pixels are taken into consideration.
- This method is in not applicable when scene object is similar to Airlight.
- It produces some Halo effects in resultant image.



Figure5. Hazy Image[2]



Figure6. Haze Free Image[2]

This method is improved version of Dark Channel Prior (DCP). Improvement is that soft-matting will be done using bilateral filter. The aim of applying bilateral filter is to smoothen the small scale textures of image. Improved Dark Channel prior is based on dark channel concept to estimate the atmospheric light and obtain better results. Most image dehazing methods only consider that use a hard threshold assumptions or user to estimate atmospheric light. The brightest pixels are sometimes the objects such as car lights or streetlights. So the wrong atmospheric light estimation may affect the dehazing results. It resolves the problem of significant region which contains sky. Means in the sky region it take patches to obtain the atmospheric light. Results of the dark channel prior gives dim image after the haze removal. So, this method has greater efficiency, less execution time and improves the original algorithm.

STRONG POINTS:

- Air light estimation is accurate.
- Computational time required is less.
- The regions containing sky becomes brighter.

WEAK POINTS:

- Halo effects are produced in some regions.
- Transmission map estimation is not accurate.



Figure7. Hazy Image[21]



Figure8. Haze Free Image[21]

3.2.3 IDCP USING GUIDED FILTER[5]

Main disadvantage of DCP and IDCP method is that they produce halo effects (blocky effects) in the output image. So IDCP with guided filter method is introducing to overcome this disadvantage. Image will be dehazed by

combining dark channel prior and guided filter. Guided Filter is an edge-preserving smoothing operator. So it could remove halo artifacts effectively Dark channel is same as DCP method and atmospheric light is estimated based on the imaging law of very dense hazy regions. In this method transmission map is refined using guided filter. Refinement of transmission map is needed to remove the halo effects

STRONG POINTS:

- Halo effects are removed efficiently.
- Refinement of transmission map is done by guided filter so resultant images are good.

WEAK POINTS:

- Airlight estimation is not accurate.
- It is not able to improve the contrast.



Figure9. Hazy Image[21]



Fig.10 Hazy Image[21]

3.2.4 DCP WITH HISTOGRAM SPECIFICATION[6]

DCP method is graceful and concise but there are some problems like thickness of haze, direct attenuation is not suitable for foreground. So due to these reasons haze free image is looking dim. When removing the haze in the image with large background area and low contrast, DCP will not give good results To overcome these problems, DCP with histogram specification has been introduced to improve the contrast of the recovered image. This is resolved by rebuilding the histogram of image. In this method image with large background area and low contrast are input images & build the histogram of hazy images together with their haze removal result. Atmospheric light and transmission map is estimated same as DCP. Histogram of haze removal image has a tendency of left-shifting and narrow, and some sharp points occur in the high intensity region, after that rebuild the histogram of haze removal image by expanding the low intensity area of the histogram and eliminating the sharp point at the high intensity area.

- Haze is removed from the low contrast & large background containing images.
- Improved contrast of the resultant image.

WEAK POINTS:

- Poor contrast of image.
- Computational time required is more.



Figure11. Hazy Image[19]



Figure12. Haze Free Image[19]

3.2.5 ANISOTROPIC DIFFUSION METHOD[20]

This method improves the contrast of an image in HSI (hue, saturation and intensity) color plane without user interference. In this method anisotropic diffusion is used to refine the atmospheric light obtained using DCP method. This method is widely used in consumer electronics, tracking and navigation, and entertainment industries, etc. For the post processing histogram stretching will be done. Post processing is the contrast enhancement technique and it can be done by various methods which are suitable for hazy image. HIS color model reduces the computation time.

STRONG POINTS:

- Estimation of Airlight is done accurately.
- Contrast is enhanced in resultant image.

WEAK POINTS:

- Transmission map is not estimated accurately.
- Visibility of the restored image is poor.



Figure13. Hazy image[21]



Figure14. Haze Free Image[21]

3.2.6 ADAPTIVE FOG REMOVAL METHOD

It is hard to recover the original color and shape of an object in a hazy image. Single image based dehazing methods with additional depth information suffer from the color distortion problem. To solve this problem the single image based algorithm using the luminance map map was introduced. In this method HSV color model is used. Estimation of atmospheric light is using dark channel prior. This method takes highest intensity (V) value in the HSV color model for the estimation of atmospheric light. It is advantageous from other techniques in the sense that the other techniques take the brightest pixel among all color channels in the foggy image. After that luminance map is generated using the luminance of the image. Luminance map can be estimated using the average color of the pixels. The luminance map is generated from the Y channel of the image. So using atmospheric light and luminance map haze could be removed easily.

STRONG POINTS:

- Airlight estimation is accurate.
- Peak Signal to Noise ratio is higher.
- It improves the image contrast.

WEAK POINTS:

- More computational time is required.

4. IMAGE DEFOGGING BASED ON IMAGE CONTRAST ENHANCEMENT

Image contrast enhancement algorithms aim to improve the contrast of the image and are widely used in the field of image defogging, underwater image enhancement, and medical image enhancement.

4.1. RETINEX MODEL FOR HAZE REMOVAL

The transmission map is more or less a constant image. From Retinex theory it is known that the illumination of an image does not vary much across the image [7]. So the idea is to obtain an estimate of the transmission map using the Retinex algorithm. Transmission map is assumed to be constant across all three color bands. So we first convert the Image into HSV space and then use the luminance component alone to find the transmission map. V is the luminance component of the image. The transmission map can be obtained by using the below equation

$$\tilde{t}(x) = F(x) * V(x) \quad (2)$$

Where,

F = Gaussian surround filter

* represents convolution.

There is no need for any refinement on this transmission map. Using this transmission map, we can directly obtain the haze free image. But there is a problem in this method; value c cannot be chosen arbitrarily.

STRONG POINTS:

- Simple and fast.
- Suitable for the foggy image with low intensity.

WEAK POINTS:

- Fail to enhance the foggy image with inhomogeneous fog.
- Cannot enhance the local information of the foggy image.

4.2 IMAGE DEFOGGING BASED ON THE TRADITIONAL IMAGE CONTRAST ENHANCEMENT METHOD

In this section, we will briefly summarize the image defogging algorithm based on the traditional image contrast enhancement method, such as the intensity transforms, homomorphic filtering, high-boost filtering, and wavelet transform.

4.2.1 INTENSITY TRANSFORMS

The histogram of the foggy image is usually distributed centrally since most pixels have large color values or gray values. Thus, the foggy image has low contrast and dynamic range. Intensity transforms are a simple and effective method which enhances the image by redistributing the histogram [8]. The power-law gamma transformation, piecewise-linear transformation, and histogram equalization (HE) are typical contrast enhancement algorithms and are widely used in the field of night image enhancement, X-ray image enhancement, and image defogging. In the field of image defogging, the power-law gamma transformation and piecewise-linear transformation are usually applied in the last step, which is used to improve the brightness of the enhanced image. Gao et al. [9] applied it to each channel of the enhanced image obtained by the MSR algorithm. Ma et al. used the piecewise-linear transformation to further improve the visibility of the enhanced image obtained by the SSR algorithm. The HE method enhances the image by redistributing the image histogram to expand its dynamic range. The HE method is divided into two categories: global histogram equalization (GHE) and local histogram equalization (LHE) [10]. The GHE algorithm can enhance the global contrast of a foggy image, but it cannot enhance the local contrast of a foggy image. For foggy images with an inhomogeneous fog distribution, the GHE algorithm cannot achieve good performance. Especially in the depth discontinuities area, the GHE algorithm leads to halo artifacts. Jun et al. [11] used the GHE algorithm to first enhance the foggy image, and then used the wavelet transform to reduce halo artifacts and noise. In order to enhance the local information of an image, various LHE algorithms and their improvements have been proposed [12]. Kim proposed a partially overlapped sub-block histogram equalization (POSHE) algorithm. The POSHE algorithm first performs the GHE algorithm on each sub-block, and then applies a weighted fusion strategy to the overlapped pixels. The POSHE algorithm not only improves the contrast of the image, but also reduces the 'block' artifacts. Patel et al. compared the performance of brightness preservation of many local histogram equalization algorithms [13]. Ramya et al. proposed a brightness preserving dynamic fuzzy histogram equalization (BPDFHE) algorithm to enhance the visibility of foggy images and to maintain color fidelity. In order to reduce the noise caused by the HE algorithm, the contrast limited adaptive histogram equalization (CLAHE) was proposed [14]. Xu et al. [8] performed the CLAHE algorithm on the intensity component of the HIS space to enhance the visibility of a foggy image while reducing the noise. Even though image contrast can be enhanced by histogram stretching, the image often appears unrealistic. This simple technique will fail when the

image has significant depth variations or there is inhomogeneous fog or haze. Directly performing the HE algorithm on each channel will change the color structure of foggy images, which causes the HE algorithm to suffer from a color distortion problem. Although we can only apply the HE algorithm to the intensity channel to reduce the color distortion, the enhanced image also encounters the problem of color degradation due to the influence of the intensity on all channels of an image of the fog. However, for some foggy images with dense fog, the visibility of the enhanced image obtained by the HE-based algorithm is better than other methods, such as the Retinex-based algorithms and physical model-based algorithms.

STRONG POINTS:

- Resultant image has high contrast.

WEAK POINTS:

- Color and edge distortion.
- Boost noise.
- ‘Halo’ effects are produced in resultant image.

4.2.2 HOMOMORPHIC FILTERING[18]

In general, in the frequency domain, the high-frequency components of an image are associated with the image area whose intensity dramatically changes, such as the edge of the image. The low-frequency components represent the flat area of an image including the sky area. The airlight component of the physical model can be regarded as the main component of low-frequency. The edge information of a foggy image is usually degraded owing to the influence of fog. In other words, the high-frequency components are decreased while the low-frequency components are increased. So if we can improve the high-frequency components and weaken the low-frequency components of an image, the visibility of a foggy image may be enhanced. The homomorphic filtering method has a model similar to the Retinex theory, but it does not need to estimate the incident component. Homomorphic filtering enhances an image by using high pass filtering to enhance the high-frequency components and reduce the low-frequency components. This algorithm is simple and fast, but it also cannot enhance a foggy image with dense fog or inhomogeneous fog.

4.2.3 HIGH-BOOST FILTERING

High-boost filtering also enhances an image by amplifying the high frequency component [8]. High-boost filtering and Retinex-based algorithms also have some similarities. The mask image of high-boost filtering can be viewed as the reflection image of the Retinex-based algorithm. High-boost filtering fuses the mask image and original image to improve the high frequency component, which can enhance the visibility and edge information of the image. This algorithm is also simple and fast. The visibility can be enhanced by the algorithm, but it will cause color distortion and noise amplification.

4.2.4 WAVELET TRANSFORM

Similar to homomorphic filtering and high-boost filtering methods, the wavelet transform also enhances an image by improving the high frequency component and reducing the low frequency component. Busch et al. proposed a fog visibility analysis method via the wavelet transformation for a traffic control system [15]. Jia et al. [16] first used the wavelet transform to decompose the luminance component of the YUV space, and then removed the airlight model by applying Gaussian filtering to the low-frequency sub-bands, and used the high-pass filter to enhance the image information in the high frequency sub-bands. Finally, the enhanced image was obtained via the inverse wavelet transform. Rong et al. used the unsharp masking algorithm to enhance the contrast of the low-frequency [17]. The wavelet-based algorithm has good performance in reducing the halo effect and noise, but the visibility cannot be improved especially for images with heavy fog or inhomogeneous fog. This is mainly because the filter used is simple and does not take into account the information of the scene. In other words, the fog component and edge information cannot be well estimated via the simple filtering. Yang et al. combined the wavelet transformation and physical model for image defogging. They used the low frequency obtained by the wavelet transform to estimate the coarse transmission, and then used the guided image filtering to optimize the transmission for image defogging.

STRONG POINTS:

- Highlighted local information or edge information of the foggy image.
- Good noise suppression.

WEAK POINTS:

- Fail to enhance the image with dense fog or inhomogeneous fog.
- May make the resultant image too bright or too dark.

5. CONCLUSION

Haze & fog removal methods have become more useful for many computer vision applications. The purpose of this paper is to review the approaches about image dehazing algorithm in conventional classification benchmark. All the dehazing methods useful for surveillance, intelligent transportation, for remote sensing and under water imaging, traffic monitoring, target identification etc. These methods are based on the partial estimation of atmospheric light. Above methods not works when the scene objects are inherently similar to the atmospheric light and no shadow is cast on them, so in future implementing the best and fast defogging method to eliminate these problems. And also work for mist, rainy and snowy and camera mis-focused images.

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