A Survey: An Approach for the Enhancement of Foggy Images

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Abstract

Fog is the natural phenomenon that causes severe difficulties in driving & results in major accidents. Fog degrades the view of an object and results in poor visibility. The poor visibility of an object becomes challenge to the driver to identify the object and monitor it. It creates lots of difficulties in driving and monitoring the vehicle. There is lots of research on the topic but still the problem has not solved to the desired result. There exist several kinds of environment variations that make the foggy image enhancement more difficult. Therefore an efficient algorithm is required to cope up with several challenges arising from the nature of visibility enhancement of foggy images.
Keywords: Enhancement image, Foggy image, Visibility image, Contrast and defogging image

I. Introduction

Fog is the visible aggregation of a great amount of water droplets and ice crystals which are suspended in the atmosphere close to the ground. These droplets and ice crystals reduces the visibility and contrast of the image which results in blurring of edge information and make the object identification very difficult. In the remote sensing system, surveillance, and intelligent vehicles, the image appearance is subject to weather condition and thus affected by smoke, haze and fog.[19] There are pros and cons of dense fog: for example, dense fog is good for tea production and growth of rubber trees but dense fog is very dangerous for aircraft landing and take-off, highway driving and navigation. In the past few decades, significant efforts in the field of image enhancement have been done to deal with bad weather conditions, so that Advance Driver Assistance Systems (ADAS), Visual Navigation Systems (VNS) and Intelligent Transport System (ITS) can be made more reliable, robust and efficient. The effect of fog on the luminance of object is modeled by Koschmieder's law with the help of following relation:

$$L(u,v) = L_0(u,v)e^{-kd(u,v)} + L_S(1 - e^{-kd(u,v)}) \ldots\ldots\ldots\ldots (4)$$

Where d (u, v) is the distance of the object at pixel (u, v) and L_s is the luminance of the sky. As described by (1), fog has two effects: first is an exponential decay $e^{-kd(u,v)}$of the intrinsic luminance $L_0(u, v)$, and second is the addition of the luminance of the atmospheric veil $L_s(1-e^{-kd(u,v)})$, which is an increasing function of the object distance d(u,v). The meteorological visibility distance is defined as $d_m = -\ln(0.05)/k$.

Original Image
Foggy Image

Fig. 1: 15Image and its foggy image [28]

Irrelevant to the sunlight or the moonlight, visibility is the ability to see through air. Clean air has a better visibility than air polluted with dust particles or water droplets. There are a number of factors affecting visibility such as fog, mist, haze, smoke, and in coastal areas sea spray. The difference between fog, mist, and haze can be quantified as the visibility distance. Visibility degradation is caused by the absorption and scattering of light by particles and gases in the atmosphere. Scattering by particles, impairs visibility more severe than absorption. Visibility is mainly reduced by scattering of light from particles between an observer and a distant object. Particles scatter light from the sun and the rest of the sky through the line of sight of the observer, thereby decreasing the contrast between the object and the background sky. Image enhancement improves our perception of information in an image by modifying its attributes in such a way that it is suitable for a specific application. Fog reduces the contrast and visibility of the scene. Visibility is simply how far you can see. In weather terms it is how clear the atmosphere and air is, taking into account fog, mist and urban pollution. Visibility can be estimated using descriptive words such as: good, poor, foggy etc. How far you can see is also used to describe visibility:

- Fog – less than 1km
- Poor – 1 to 5km
- Moderate – 5 to 10km
- Good – more than 10km

Different environments around the world experience different levels of fog. People living high in the mountains may see fog all year. The city of San Francisco in North America is famous for its thick mist that moves in from the Pacific Ocean. In the United Kingdom we mainly see fog in autumn and winter, but some tropical parts of the world may never have seen fog. There are two commonly used methods to enhance the image: spatial domain based method and frequency domain based methods. Spatial domain based methods are easy to understand and have low complexity. These methods operate directly on the pixels. These methods are mainly based on histogram equalization. These methods are further divided in to two categories: Global Histogram Equalization (GHE) and Local Histogram Equalization (LHE). Global histogram equalization has certain drawbacks such as overstretching and noise enhancement. While local histogram equalization has certain benefit over global histogram equalization. Frequency domain based methods are more complex and operates directly on the transform coefficient of the image such as Fourier transformation, Discrete Wavelet transformation and Discrete Cosine transformation. The limitation with frequency domain image enhancement is that it cannot simultaneously enhance all parts of the image very well and these methods are difficult to automate.

II. LITERATURE REVIEW

Jean- Philippe et al. in [1] proposed a new scheme for rating visibility enhancement algorithms based on the addition of several types of generated fog on synthetic and camera images.

Zhiynan Xu et al. in [2] presented a Contrast Limited Adaptative Histogram Equalization (CLAHE). Each time an image is acquired, window and level parameters must be adjusted to maximize contrast and structure visibility. CLAHE was originally developed for medical imaging and has proven to be successful for enhancement of low-contrast images such as portal films.

Cheng Lei et al .in [3] presented a fast dynamic histogram equalization (FDHE) algorithm. FDHE expanded the image gray distribution, balanced the gray-scale distribution and processed speed to meet real-time requirement.

Yan Feng et al. in [4] proposed a method for foggy image enhancement that integrates multilevel wavelet decomposition, the auto-adapted LUM filter, soft threshold and so on. Firstly, carry on the multilevel wavelet decomposition to the image, and then obtain the low-frequency component and high-frequency components of image.

Chen Xianqiao et al .in [5] presented a new algorithm for foggy image restoration in traffic, which is based on histogram equalization. The useful information in low brightness area is preserved and the histogram of the sky area is translated and narrowed down. The enhancement area of useful information is enlarged and its computational complexity is low compared with the degraded model.

J.-P. Tarel et al. in [6] proposed a novel algorithm and variants for visibility restoration from a single image. The main advantage of the proposed algorithm compared with other is its speed: its complexity is a linear function of the number of image pixels only. This speed allows visibility restoration to be applied for the first time within real-time processing applications such as sign, lane-marking and obstacle detection from an in-vehicle camera.

N. Hautiere, J.-P.Tarel, and D. Aubert in [7] presented a new algorithm. According to the algorithm Fog density is first estimated and then used to restore the contrast using a flat-world assumption on the segmented free space in front of a moving vehicle. A scene structure is estimated and used to refine the restoration process

S. G. Narashiman and S. K. Nayar in [8] proposed an automatic method based on physical model and maximum entropy to remove weather effects using only a single image. First, segment the sky region by optimal estimated normal distribution and select the lowest point of the sky region as the vanishing point. Then, exploit the physics-based model to remove weather effects from the image. At last, to overcome the defect of a single image lacking exact atmospheric information, an algorithm is proposed based on maximum entropy to select the optimal scattering coefficient of the atmosphere.

N. Hautière, J.-P. Tarel, and D. Aubert in [9] proposed a new scheme. Weather conditions are first estimated and then used to restore the contrast according to a scene structure which is inferred a priori and refined during the restoration process. Based on the aimed application, different algorithms with increasing complexities are proposed.

R. Tan, N. Pettersson, and L. Petersson in [10] develop a method that requires solely a single image taken from ordinary digital cameras, without any additional hardware. The method principally uses color and intensity information. It enhances the visibility after estimating the color of skylight and the values of airtight. The experimental results on real images show the effectiveness of the approach.

R. Tan in [11] introduced an automated method that only requires a single input image. This method is based on two basic observations: first, images with enhanced visibility (or clear-day images) have more contrast than images plagued by bad weather; second, air light whose variation mainly depends on the distance of objects to the viewer tends to be smooth. The method does not require the geometrical information of the input image, and is applicable for both color and gray images.

Jisha John and M.Wilsey in [12] proposed a novel approach is proposed in this paper that is used to enhance degraded video sequences. It enhances visibility of the frames and also maintains the color fidelity. First a background image is estimated for the video sequence. The enhancement method is then separately applied on this background image and on the estimated motion pixels. The enhancement method consists of three phases. The first phase estimated a global correction parameter and the second phase computes an approximate degradation measure. In the final phase a novel wavelet fusion method is used to obtain the enhanced frame.

S.G. Narasimhan et al. in [13] proposed a fast algorithm to restore scene contrast. The methods described in this paper are effective under a wide range of weather conditions including haze, mist, fog, and conditions arising due to other aerosols. Further, the methods can be applied to gray scale, RGB color, multispectral and even IR images.

Gong Chen et al. in [14] presented a novel method for moving object detection in foggy days. Firstly, surveillance video under foggy weather is defogged, leveraging a physics-based image restoration approach. Then exploit a novel background maintenance algorithm based on the Unscented Kalman Filter (UKF) to subtract the background from the defogged video. Finally, moving objects are segmented by background differencing

Gupte S. et al. in [15] presented algorithm for vision-based detection and classification of vehicles in monocular image sequences of traffic scenes recorded by a stationary camera. Processing is done at three levels: raw images, region level, and vehicle level. Vehicles are modelled as rectangular patches with certain dynamic behaviour. The proposed method is based on the establishment of correspondences between regions and vehicles, as the vehicles move through the image sequence.

Kaushik Deb et al. in [16] proposed a method that is very effective in coping with different conditions such as poor illumination and varied weather comparing with traditional approaches. Experimental results show that the distance from the vehicle varied according to the camera setup.

J. A. Stark in [17] proposed a scheme for adaptive image-contrast enhancement based on a generalization of histogram equalization (HE). A key feature of this formalism is a “cumulation function,” which is used to generate a grey level mapping from the local histogram. By choosing alternative forms of cumulation function one can achieve a wide variety of effects.

Y. T. Kim in [18] proposed a novel extension of histogram equalization to overcome such a drawback of histogram equalization. The essence of the proposed algorithm is to utilize independent histogram equalizations separately over two sub images obtained by decomposing the input image based on its mean with a constraint that the resulting equalized sub images are bounded by each other around the input mean.

Y. Wang, Q. Chen, and B. Zhang in [19] proposed a novel histogram equalization technique, equal area dualistic sub-image histogram equalization, is put forward in this paper. The simulation results indicate that the algorithm can not only enhance the image information effectively but also preserve the original image luminance well enough to make it possible to be used in a video system directly.

S. D. Chen, and A. R. Ramli in [20] proposed a novel extension of BBHE referred to as minimum mean brightness error bi-histogram equalization (MMBEBHE) to provide maximum brightness preservation. BBHE separates the input image's histogram into two based on input mean before equalizing them independently. This paper proposes to perform the separation based on the threshold level, which would yield minimum absolute mean brightness error (AMBE - the absolute difference between input and output mean).

Srinivasa G. Narasimhan, Shree K.Nayar in [21] presented a fast algorithm to restore scene contrast. In contrast to previous techniques, our weather removal algorithm does not require any a priori scene structure, distributions of scene reflectances, or detailed knowledge about the particular weather condition. All the methods described in this paper are effective under a wide range of weather conditions including haze, mist, fog, and conditions arising due to other aerosols.

SermsakJaruwatanadilok, AkiramIshimaru, Yasuo Kuga in [22] presents a study of optical imaging through clouds by using the point-source vector radioactive transfer theory. The point-spread function including complete polarization characteristics is presented with numerical examples at 1 μm wavelength showing the effects of aperture size and optical depth on the shower curtain effects.

Srinivasa G. Narasimhan, Shree K.Nayar in [23] presented a fast physics-based method to compute scene structure and hence restore contrast of the scene from two or more images taken in bad weather In contrast to previous techniques, this method does not require any a priori weather-specific or scene information, and is effective under a wide range of weather conditions including haze, mist, fog and other aerosols.

LIU Guo-jun et al. in [24] presented a novel contrast enhancement approach based on wavelet transform and fuzzy logic. They utilize nonlinear operator on high-pass coefficients to enhance the details of images. Finally, the inverse wavelet transform is applied to map the result into space domain. The experimental results demonstrate that the approach is very effective in enhancing the low contrast image.

Hardic R C, Boncelet C G. LUM in [25] introduced a new class of rank-order-based filters, called lower-upper-middle (LUM) filters. The output of these filters is determined by comparing a lower- and an upper-order statistic to the middle sample in the filter window. These filters can be designed for smoothing and sharpening, or outlier rejection. This flexibility allows the LUM filter to be designed to best balance the tradeoffs between noise smoothing and signal detail preservation. LUM filters for enhancing edge gradients can be designed to be insensitive to low levels of additive noise and to remove impulsive noise.

Zhou Pei, Zhu Hong, QianXueming in [26] proposed a wavelet fusion method. Wavelet transform, histogram equalization and non-linear operator are used to process synthetically fog-degraded Image based on the existent image enhancement method. Histogram equalization is processed fog-degraded image firstly, then wavelet transform is used to decompose the image, non-linear operator is used to enhance high-frequency part of the decomposition image lastly.

Fang Xiaohong, LiuXiaoshun in [27] proposed an approach that is applied to the recognition of degraded traffic signs with promising results. In order to cope with the degradations, the Combined Blur and Affine Invariants (CBAIs) are adopted to extract the features of traffic sign symbols without any restorations which usually need a great amount of computations.

Chen XQ, Yan XP, Chu, XM in [28] proposed a new algorithm FSSR for this topic, which is based on SSR algorithm. The algorithm FSSR keeps the good enhancement results, and computation task is reduced evidently.

Sos Agaian, Mehdi Roopaei in [29] Proposed scheme works for different hazing cases such as smoky and foggy images. The basic steps of the presented algorithm are: at first an optimized histogram mapping function is applied on original images. In the second step, every channel is added with a combination of original and the related filtered channel. A coordinate transformation from RGB color model to HSV and applying CLAHE enhancement on the v-channel would be assigned at the end of procedure.

Inhye Yoon et al. in [30] proposed a method that can significantly enhance the visibility of foggy UAV images compared with existing monochrome model-based defogging method. The proposed algorithm can enhance the visibility by removing atmospheric degradation factor in airborne images acquired by aerial platforms such as satellite, airplane, and UAV under critical weather conditions such as haze, fog, and smoke.

Xuesong Jiang et al. in [31] presented a real-time night video enhancement approach. As
observed that a pixel-wise inversion of a night video has quite similar appearance with the video acquired at foggy days. This paper presented an improved dark channel prior model and integrates it with local smoothing and image Gaussian Pyramid operators.

Geofeng MENG et al. in [32] proposed an efficient regularization method to remove hazes from a single input image. The method benefits much from an exploration on the inherent boundary constraint on the transmission function. This constraint, combined with a weighted L1−norm based contextual regularization, is modeled into an optimization problem to estimate the unknown scene transmission.

Ili Ayuni Mohd. Ikhsan et al. in [33] this paper analyzed various methods of preprocessing techniques for vertebral bone segmentation. Three methods are considered which are histogram equalization (HE), gamma correction (GC) and contrast limited adaptive histogram equalizer (CLAHE). This work aims to compare and quantify the precision and accuracy of the techniques that are used to enhance the image quality.

Lark Kwon Choi et al. in [34] proposed a referenceless perceptual defog and visibility enhancement model based on multiscale "fog aware" statistical features. This model operates on a single foggy image and uses a set of "fog aware" weight maps to improve the visibility of foggy regions.

Vigneswaran T et al. in [35] presented a new method for foggy image enhancement that integrates multilevel wavelet decomposition, the auto-adapted LUM filter, quadratic thresholding function and so on.

A. Inferences Drawn out of Literature Review:

It can be observed from the literature discussed in the previous section that there are two commonly used methods to enhance the image: spatial domain based method and frequency domain based methods. [17] Spatial domain based methods are easy to understand and have low complexity. These methods operate directly on the pixels. These methods are mainly based on histogram equalization. These methods are further divided in to two categories: global histogram equalization and local histogram equalization. Global histogram equalization has certain drawbacks such as overstretching and noise enhancement. While local histogram equalization has certain benefit over global histogram equalization. Frequency domain based methods are more complex and operates directly on the transform coefficient of the image such as Fourier transformation, Discrete Wavelet transformation and Discrete Cosine transformation. Frequency domain methods are further divided into three categories: Image Smoothing, Image Sharpening, and Periodic Noise Reduction by Frequency Domain Filtering.[25] The limitation with frequency domain image enhancement is that it cannot simultaneously enhance all parts of the image very well and these methods are difficult to automate. However, in real-world situations, there exist several kinds of environment variations that make the foggy image enhancement more difficult. Therefore an efficient algorithm is required to cope up with several challenges arising from the nature of visibility enhancement of foggy images.

III. CONCLUSION

This paper is an effort to present the survey of most recent papers in the field of vision enhancement of foggy images.

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