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A Comprehensive Study on Haze Detection Techniques

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Abstract: Image acquired by the visual systems is degraded under hazy weather, which affects the tracking, detection and recognition of targets. Thus, restoring the true scene from hazy image is of great significance. The main goal of this paper was to summarize current method of haze detection and dehazing algorithms. And to present the problems of image dehazing which need to be further studied.

Keywords: Hazy image classification, image dehazing, image quality assessment, visibility distance.

INTRODUCTION

Bad weather (fog, haze, mist) reduces atmospheric visibility which degrades image quality and performance of many applications like video surveillance, object detection, tracking, object recognition, remote sensing system and intelligent vehicles. Hence, it is necessary to make these vision algorithms robust to weather changes. Depending on the size and type of particles, weather conditions have broadly classified into two categories: Steady and Dynamic weather [1,2].In former one, the particle size is small(1-10μm).In latter, size of particles is 1000 times larger than those of the steady weather(0.1-10 mm).The former one includes Haze, Fog, and Mist and Dynamic weather include Snow and Rain[3,4]. Haze is the aggregation in the atmosphere of a very fine, widely dispersed, solid or liquid molecules, or both resulting in an opalescent appearance in the air that subdues color. It comprises of aerosol particles suspended in the gas. The size of haze particles is larger than air molecules but smaller than fog droplets. When pollutants and smoke are not able to disperse, they cling together to form a hazy cloud at a low level.

Table 1: Weather condition and associated particle type, visibility and weather condition

Weather Condition	Visibility	Particle Type	Weather Condition
Fog	< 1 km	Water Droplet	Cloudy
Mist	Between 1 km and 2 km	Water Droplet	Moist
Haze	Between 2 km and 5 km	Aerosol	Dry

Haze degrades the perceptual image quality and efficiency of computer vision algorithms. Hence, removal of haze from images as a preprocessing increases the accuracy of computer vision algorithms. Removal of haze is also important for the consumer electronics, tracking and navigation application and entertainment industries. A feature point detector can fail if images have low visibility. Hence, if the haze is removed and image is enhanced, then feature point detector can work with higher accuracy. Most of the existing image dehazing algorithm do not take account the factor of whether there is haze or not.

However, for an intelligent dehazing algorithm, the judgment method of the hazy and non-hazy image is very important. The structure of this paper is as follows. In Section II, we shall first provide methods to judge whether an image needs to be processed. Section III summarizes many dehazing algorithms. Section IV introduces some quality assessment criteria which are widely used to compare different image dehazing algorithms. Finally, we summarize the paper and present some problems which need to be studied in the future.

HAZE DETECTION TECHNIQUES

The existing dehazing algorithms are always directly applied to the image regardless of the presence or absence of haze. They couldn't make a valid identification of the image state which is haze or non-haze. But for real world applications, it is necessary to know whether the image acquired in the current

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environment needs to be processed by a dehazing algorithms. The need of doing so is that visibility restored image obtained by dehazing algorithm may be worse than the original image if no decision is made. Also, the use of the dehazing algorithm is time consuming, which is not beneficial to realize the real time target tracking, detection and recognition. Broadly, there are two methods which can judge whether the current scene has haze or not, as shown in Figure 1. The Haze detection methods assume the invisible area of image as the foggy image. It is based either on semi-inverse image or on meteorological visibility distance. Ancutiet al.[5] first proposed a haze area detection algorithm based on the semi-inverse image. This algorithm is based on the fact that the intensity values of pixels in the hazy area of the image are usually bigger than those of pixels in the clear area. The semi-inverse image M is obtained by selecting the maximum of the original image pixel and its inverse image pixel which is calculated as

$$M^c(y) = \max[S^c(y), 1 - S^c(y)] \qquad (1)$$

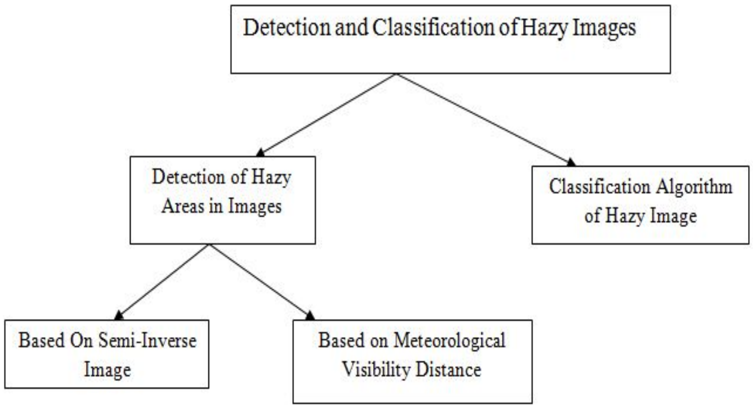

Fig. 1: The Categories of Detection and Classification of Hazy Image.

Here c denotes one of the RGB channel, S is the original image and $1 - S^c(y)$ is the inverse image of the original image.

In the sky or hazy area of an image, pixels usually have a high intensity in all color channels, i.e$S^c_{haze}(y) > 0.5$. Hence, the semi-inverse image will have the same value as the original image in these areas. Then, the difference between the original image and its semi-inverse image is calculated so that the hazy area can be easily detected. This method detects haze only in hazy image but it is not suitable for the judgment of whether the current image has haze or not.

Hautiere and Tarel et al. [6] proposed a daytime haze detection method based on calculating the meteorological visibility distance. In this algorithm, Canny-Deriche filter is used to extract the image contours so as to highlight the edges of roadways. Then to find the road surface layer, the region growing algorithm is used. Finally, the visibility distance of the image was obtained by calculating the measurement bandwidth. This algorithm uses horizontal line to denote the visibility distance. The region above the horizontal line usually has low contrast and is regarded as the hazy area or invisible area.

Fattal [7] estimates the albedo of the scene and then infers the medium transmission, under the assumption that the transmission and surface shading are locally Un-correlated. This approach may be failed in heavy foggy cases, where the assumption is broken.

He at al. [8] proposes a simple but effective image prior, to detect fog using a fix color camera. It is based on a key observation: most local patches in foggy-free images contain some pixels which have very low intensities in at least one color channel. The dark channel prior may be invalid when the scene object is inherently similar to the airlight over a large local region and no shadow is cast on the object.

Bronte et al.[9] also detected the hazy area of an image by estimating the visibility distance but it also has some shortcomings. One of them is that the system sometimes also detects haze when it is really not present. This is because the sun sometimes is very bright and saturates the camera. As a consequence, the segmentation process fails. It can not be considered as a failure, because the sun effect is very similar to the fog one, provoking a short visibility distance that makes very difficult for a normal driving, i.e. on sunrise and sunset.

While detecting haze by using classification algorithm, we need to create an image library which contains large amounts of clear images and hazy images. The method extracts some features which have large difference between the two types of images, and then uses an effective classifier to train the features and obtain the classification. Finally, a query image can be classified as a hazy image or clear image.

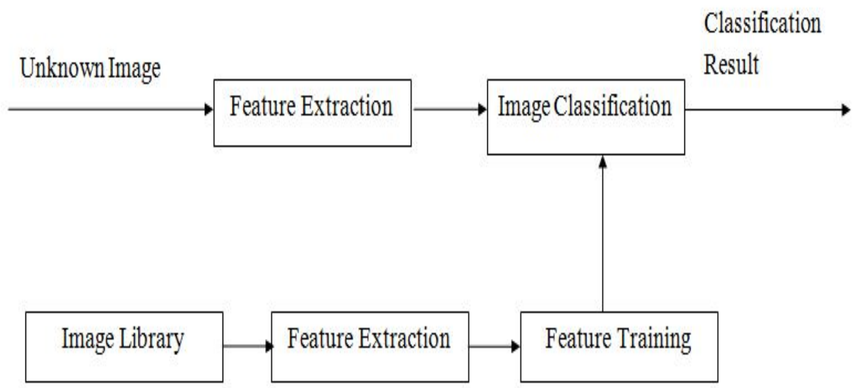

Fig. 2: The Flowchart of Hazy Image Classification

In haze classification method, the features are the most important and directly determine the classification accuracy. Till now there is no feature that can accurately classify the hazy image and clear image. Yu et al[10] uses image visibility, the intensity of the dark channel image and the image visual contrast as features and used the support vector (SVM) for hazy image classification. Pavlicet al.[11] uses power spectrum of the Fourier Transform as the global feature and SVM for hazy image classification for the vehicle visual system on highways. Li et al. [12] pointed out that for image visibility feature image brightness and edge information is important and is calculated by the meteorological visibility distance. Zhang et al.[13] consider the angular deviation between each hazy image and a clear image of the same scene as features for hazy image classification. Although their method can obtain good classification performance, it is hard to simultaneously obtain a clear image and hazy image of the same scene in real world application.

DEHAZING ALGORITHMS

In many literatures, based on whether a physical model is used or not, the image dehazing algorithms are categorized into three categories [14] i.e. image restoration based method, image enhancement based and fusion based. In image restoration method, estimation of physical model parameter is done like atmospheric light and depth (transmission). In it, restored image is obtained by inversely solving the physical model. The main aim of these methods is to obtain a natural and clear image which has good visibility while maintaining good performance on color restoration.

In Image enhancement based method, physical model is not used. It uses various image enhancement methods like histogram equalization and its variants. All these methods have a problem in preserving color fidelity. These methods are useful for the images whose properties are roughly constant across the image. In fusion based dehazing algorithm multiple images are fused to enhance the image.

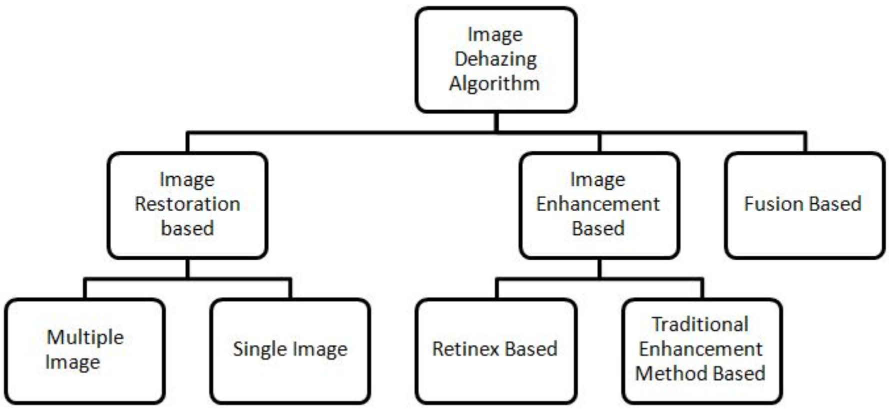

Fig 3: The categories of image dehazing algorithms.

QUALITY ASSESSMENT CRITERION

The main purpose of image dehazing is to enhance the visibility of a hazy image. A good dehazing algorithm not only needs to enhance the visibility, edge and texture information but also to preserve image structure and colors. An image with good visibility also means that it has obvious edge and texture information. Hence, a good image quality assessment method needs to compare the effect of visibility, image structure similarity and color restoration of different dehazing algorithms.

No-reference [15], full-reference [16] and reduced- reference [17] are the three categories of image quality assessment criterion. As a clear image corresponding to the hazy image is required in full-reference and reduced-reference, it is hard to be satisfied in real applications. Hence, in the field of image dehazing, the no-reference metric is widely used, such as average gradient, structural similarity (SSIM), information entropy, global contrast and peak-to-signal noise ratio (PSNR).

To compare the visibility of images there are various indexes like blind assessment indicator, image contrast, image visibility measurement and visual contrast measure.

Blind Assessment Indicator

The first two indicator $(l, \overline{r})$ of the blind assessment uses the enhanced degree of image edges to represent the enhanced degree of the image visibility [18]. The first indicator l denotes the increased rate of visible edges after image dehazing and is calculated by

$$l = \frac{m_p - m_q}{m_q} \qquad (2)$$

Where m_p and m_q represent the cardinal number of the set of visible edges in restored image I_p and the original image I_q respectively.

The second indicator $\overline{r}$ represents the restoration degree of the image edge and texture information.$\overline{r}$ is calculated as

$$\overline{r} = exp[\frac{1}{m_p} \sum_{i \in p} \log p_i] \qquad (3)$$

Larger $\overline{r}$ means that the corresponding dehazing algorithm has better edge preservation performance than others.

Table 2: The comparison of some typical image dehazing algorithms

Dehazing Method	Advantages	Disadvantages	Applications
Multiple Images obtained under different weather conditions of the scene	Colors are restored well	Fail to restore dense hazy images or inhomogeneous hazy image. Hard to obtain the source images.	Special applications such as thin hazy weather.
Multiple images obtained under the same weather of the scene	Good color fidelity, high image visibility under thin haze.	Hard to take the source images. Atmospheric light value is manually set.	The scene with unmoving camera and thin hazy weather.
Fattal[19]	High image visibility under inhomogeneous haze or thin haze.	Fail to enhance the image with dense haze or insufficient signal-to-noise ratio.	Single color hazy image.
Tan et al.[20]	Good contrast of the hazy image	Hazy image may be overly restored and accured 'Halo' effect and color distortions.	Single color or gray hazy image.
Retinex Based	Suitable for hazy image with low intensity	Cannot enhance local information of the hazy image. Fail to enhance inhomogeneous haze.	Single color or gray image with low intensity.
Intensity Transform	Resultant Image has high contrast	Boost noise Color and edge distortion	Single color or gray image
Bayesian Dehazing[21]	High visibility for hazy image	Edge degradation and color distortion High computational cost	Single color hazy image
Learning Based[22]	Suitable for all scenes	Lack of perfect learning model Hard to maintain in case of large dataset	Color images
Wavelet Transform	Good noise suppression. Highlights edge information in hazy images	Make resultant image too bright or too dark.	Single color or gray image with thin or homogenous haze
Fusion based	Fusion based perform better than single image dehazing algorithm	Approach is complex and leads to a low efficiency.	Single color or gray images.

Image Contrast

The contrast of a clear image is usually much higher than that of a hazy image, so image contrast can be used to compare different dehazing algorithms. The higher the contrast of the enhanced image, the better is the dehazing algorithm. For an image with size$X \times Y$, its mean contrast is

$$\overline{C} = \frac{1}{XY}\sum_{i=1}^{X}\sum_{j=1}^{Y} C(i,j) \qquad (4)$$

Contrast Gain denotes the mean contrast difference between the enhanced image and original hazy image[23].

$$C_{gain} = \overline{C_E} - \overline{C_O} \qquad (5)$$

Where $\overline{C_E}$ and$\overline{C_O}$ represents the mean contrast of the enhanced and original image respectively.

Image Visibility Measurement (IVM)

The IVM [24] is defined as

$$IVM = \frac{n_r}{n_{total}} log \sum_{i\in\delta} C(x) \qquad (6)$$

Here n_r represents the number of visible edges, n_{total} is the number of edges,$C(x)$ is the mean contrast and δ denotes the image area of visible edges.

Visual Contrast Measure (VCM)

To quantify the degree of the visibility of the image VCM is used [25]. It is calculated by:

$$VCM = 100 \ * {}^{R_v}/_{R_i} \qquad (7)$$

Here R_v is the number of local areas andR_t is the total number of local areas.

CONCLUSION

This paper only summarizes various image haze detection techniques and dehazing algorithms, but many difficulties have to be overcome. The main problems are as follow:

There is no perfect criterion to judge whether an image is a hazy image or clear image. It is hard to determine whether natural clear images which look blurry are needed to be processed or not.

There is no single image dehazing algorithm that can obtain good performance in all kinds of hazy weather. When haze is unevenly distributed in an image or an image is full of dense haze, some single image dehazing algorithms will fail.

Most of the existing dehazing algorithms parameters need to be set manually. Hence, these algorithms are unrealistic in real-time application.

There is no effective set of features to recognize hazy image.

Some of the existing quality assessment index is hard to apply on different dehazing algorithms. Thus, a better quality assessment index also needs to be proposed.

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