Review on State of Art Image Enhancement and Restoration Methods for a Vision Based Driver Assistance System with De-weathering

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Abstract - **The mission of intelligent vehicles is to assist the driver in decision making. The researchers have paid attention on developing various driver assistance systems in order to assure road safety. Most of the driver assistance systems do not produce accurate results in poor weather conditions. Poor visibility is considered to be a main reason for accidents. When the weather is poor (haze, fog, darkness, snow etc...) the driver cannot get a clear view of the road. Images of outdoor scenes captured in bad weather are severely degraded. Most of the outdoor vision applications require robust detection of image features.**

The main aim of the paper is to review state-of-art image enhancement and restoration methods for a Vision based Driver Assistance System which will help the driver by providing a clear view of the road when the weather is bad. This process is called "De-weathering". Reasons for degradation are explained in order to provide the scientific background of the problem. Various image enhancement methods are reviewed in this paper such as interactive de-weathering, de-weathering using multiple images, model based methods, non-model based methods and image de-noising, in order to find a suitable approach for the vision based driver assistance system.

Keywords- Image de-weathering; vision enhancement; Computer vision; Image de-noising;

I. INTRODUCTION

Technology is rapidly increasing the capabilities of modern vehicles as the field of transportation systems covers a broad variety of technologies such as pedestrian tracking, road lane detection, automatic break system, etc…

But in various weather conditions the quality of the images grabbed by in-vehicle cameras (visible light range) is degraded [1]. Due to the above reason the accuracy of driver assistance systems depends on cameras which are sensitive to weather conditions.

Apostoloff, [2] believes that the human driver is the most unreliable component of the driving process. If responsibility is taken away from the human driver, the safety of the overall system will be increased. Poor visibility on the roads is regarded as the main cause for many accidents in the world. Images of scenes captured in bad weather (rain, fog, haze) degrade significantly because of the severe reduction in contrast and colour. Most outdoor vision applications suffer from that issue. [3].

The main purpose of this paper is to present a brief overview of these areas, in order to facilitate a better understanding of the state-of-the-art in vision enhancement techniques for driver assistance systems. The advantages and disadvantages of previous work will be discussed in order to find a suitable approach for a vision based driver assistance system.

II. REASONS FOR DEGRADATION OF THE IMAGE

The reason for bad vision is the presence of the considerable number of atmospheric particles with significant size and distributions in the participating media.

Condition	Particle type	Radius (μm)	Concentration (cm^{-3})
Air	Molecule	10^{-4}	10^{19}
Haze	Aerosol	10^{-2}–1	10^{3}–10
Fog	Water droplet	1–10	100–10
Cloud	Water droplet	1–10	300–10
Rain	Water drop	10^{2}–10^{4}	10^{-2}–10^{-5}

Figure 1: Weather conditions and associated particle types, sizes and concentrations [4]

The degradation level is increased with the distance from camera to the object due to the following reasons specified by Zimmerman et al., [5]

1) Light reflected from the object surface is attenuated due to the scattering by particles such as Molecule, aerosol, water droplet and water drop
2) Some direct light flux is scattered toward the camera/eye. Scattering of the light is caused by refraction. When light passes from one medium to another, the speed is changed and it is the main reason for deflection. The whole process is called

"refraction". Therefore, an efficient mechanism is essential to overcome this problem.

III. INTERACTIVE DE-WEATHERING

Narasimhan and Nayar, [6] have proposed an image enhancement technique based on an atmospheric scattering model. Three interactive algorithms are developed to remove weather effects. 1) Dichromatic colour transfer 2) De-weathering using depth heuristics 3) Restoration using planar depth segments. These algorithms require the interaction of the user.

TABLE I. ALGORITHMS FOR INTERACTIVE DE-WEATHERING

Method	Description
Dichromatic colour Transfer[6]	Colours of near scene points are less corrupted by bad weather than the distant scene points Transfer colours from nearby regions to replace colours of regions that are most affected by bad weather. The user has to select a good region of the image (where colours are less corrupted) and the sky region
De-weathering using depth heuristics[6]	Vanishing point is required and should be selected by the user This algorithm[6] can be used for both colour images and grey scale images
Restoration using planar Depth segments[6]	This method is used for urban scenes. Rough depth information is required

Dichromatic Colour transfer has major limitations. If the colours in the affected region do not have relevant colours in the selected "good" region this algorithm fails to produce accurate results. So this algorithm does not suit for a driver assistance system.

Interactive de-weathering does not require multiple images, which can be considered as a great advantage. But interactive de-weathering needs to estimate four parameters in order to remove weather effects. And also vanishing point is selected manually [7]. Vision enhancement system of a driver assistance system should use minimum interaction with the user. It is not practical for the driver to provide various inputs to the systems while driving. So, after considering above reasons the author believes that interactive de-weathering is not appropriate for driver assistance systems.

IV. DE-WEATHERING USING MULTIPLE IMAGES

Narasimhan and Nayar, [4] proposed a method to remove weather effects by constructing a 3D structure using two or more bad weather images.

This method is not suitable for a driver assistance system. While driving, it is not practical to get multiple images of the same scene under different weather conditions such as fog, haze and rain. According to Yuhui et al., [7], it may be impossible to get multiple images in many cases. This method is appropriate as a plug-in for image processing software such as Adobe Photoshop [6]. Adobe Photoshop uses effective algorithms for image enhancement which requires the interaction of the user. The algorithms produce great results but the algorithms are not shared publicly.

As a solution for the above scenario Xin and Zhenmin, [8] has discussed a method to remove weather effects from a single image using physical model and maximum entropy theory. Further, it is mentioned that this method does not require precise information about the scene depth and the weather conditions. Researchers pay their attention on developing de-weathering techniques which provide better output with less input.

V. IMAGE ENHANCEMENT

Contrast enhancement techniques are divided in to two classes. 1) Non model based 2) model based [9].

A. Non-model based methods

Non-model based methods use the information in the image for processing. Histogram equalization is the best example for this method[10]. It can be categorized into two classes such as global histogram equalization and adaptive histogram equalization (also known as local histogram equalization). Global Histogram equalization is the most popular for its simplicity and effectiveness. Although it is simple and popular, some contrast loss occurs as the method does not take the local image information into account. Local histogram equalization [11] is used in order to overcome the shortcomings [12]. Although it has given better results Zhiyuan et al., [13] has identified few problems such as slow speed and enhancement of noise. Contrast Limited Adaptive Histogram Equalization is used to overcome such problems[13].

Other non-model based methods are Retinex [14], wavelet based methods [15].

Retinex Algorithm

"The retinex is an image enhancement algorithm that improves the brightness, contrast and sharpness of an image"[16].

The aim of the algorithm is to obtain a balance between the human vision and the machine vision.

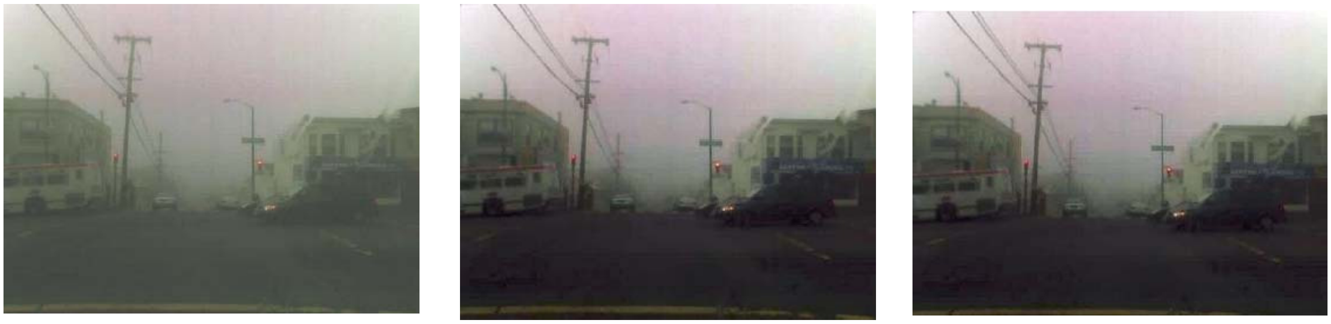


Figure 1. Retinex algorithm results [14]. Left: Original image. Middle: SSR output. Right: MSR output.

It takes the colour consistency into consideration too. Edward Land proposed the theory of retinex in 1986 after a sound research in human brain reactions to the perception of colour under various illumination conditions[14]. The retinex algorithm is divided into two classes such as 1) Single – scale retinex (SSR) 2) Multi – scale retinex (MSR) 3) Multi scale retinex with colour restoration (MSRCR) [14]. Xin and Zhenmin, [8] observe that this method provides a better output only for colour images. But it cannot be considered as a major drawback of the algorithm. This algorithm suits a real time vision based driver assistance system because of the performance. According to [16], this algorithm can produce a maximum performance of 34.1fps (frames per second). This is higher than the real time requirement of 30fps. Wang et al., [15] has compared the results of wavelet transform with weighted average arithmetic (WAA) and Laplacian pyramid transform (LPT) using six guide lines.1) standard deviation 2) entropy 3) RMSE 4)NLSE 5)PSNR 6)average gradient. It is observed that wavelet transform produces better results than WAA and LPT.

There are disadvantages of the non-model based methods. The major issue is the problem with colour fidelity[9]. According to Yuhui et al., [7], histogram equalization methods do not take the distance of scene point into account. It is observed as the main reasons for not getting an effective output. Li et al., [17] propose a novel image enhancement algorithm based on global histogram which has the ability to overcome the colour distortion.

B. Model based methods

Model based methods use physical models to predict the pattern of image degradation**.** Physics based methods provide a better output.

The main disadvantage of physics based method is that it requires extra information about the imaging equipments or imaging environment [9].

Researchers have treated various poor weather conditions such as haze, fog, rain with separate methods.

- **De-rain**

The visual effects of rain are complex. E.g.: small size, high velocity and spatial distribution [18]. Further, it is highlighted that the effects of rain on vision systems have not been previously explored. Barnum et al., [19] present a method to detect rain or snow streaks and reduce or increase the effect of it. The statistical characteristics of rain and snow are used in this method in order to produce better results. This feature can be considered as being very effective for a driver assistance system. The main disadvantage is the high computation power that is required for processing.

- **De-fog**

Phenomenology of Fog

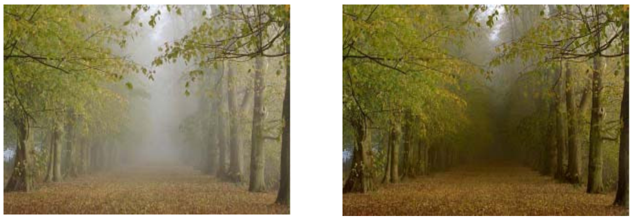
"Fog can be described as a cloud of small water droplets near ground level that is sufficiently dense to reduce horizontal visibility to less than 1,000 m (3,281ft)"[20].

Yi-Shu and Xiao-Ming, [12] discuss a fog degraded image enhancement algorithm based on a moving mask. It is assumed that the pixels in a mask have the same scene depth. Over enhancement is avoided by segmenting the sky region.

(a) (b)

Figure 2. Image enhancement algorithm based on moving mask [12]. (a) input image. (b) final fog-free image

According to Desai et al., [21] de-weathering a fog degraded image is a mathematically ill-posed problem. A novel fuzzy logic based algorithm is proposed in order to solve the problems in de-weathering fog degraded images. Mengyang et al., [22] propose a method for defogging using dark channel prior with an iterative algorithm.



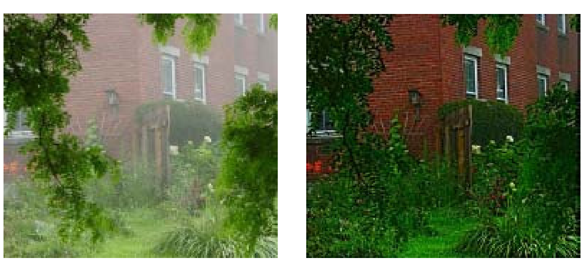
(a) (b)

Figure 3. Dark Channel Prior results [22]. (a) input image. (b) final fog-free image

This is a major component of the proposed driver assistance system. The accuracy of other features such as vanishing point detection and pedestrian tracking will rely on the visibility. If the image which is acquired from the system is degraded due to fog, it would affect the accuracy results in a bad way.

- **De-haze**

Haze is a commonly used term in image analysis, referring to a set of atmospheric effects that reduce image contrast [23]. Removing haze is an important feature for most vision systems. Guo et al., [24] propose a simple and effective method for visibility restoration from a single image. This method does not require the interaction of the user. So, it can be used in practical real time applications. The methods explained in interactive de-weathering are also useful when it comes to an offline system.



(a) (b)

Figure 4. Haze removal results [24]. (a) input image. (b) haze-free image

Dark Channel Prior is also used to remove haze from a single image. Further, it is mentioned that it can estimate the thickness of the haze and recover a haze free image in good quality.[25]

Mengyang et al., [22] observe that Dark Channel Prior results in larger saturation values in some specific situations. An iterative algorithm is proposed to adjust the colour distortion effected by higher saturation.

Various methods are proposed for image enhancement. According to the above details, the global histogram equalization is not suitable for the proposed driver assistance systems because that method does not pay attention on scene depth. Many modifications are also available for histogram equalization. Many image enhancement techniques are used for de-rain, de-fog, and de-haze.

From the features mentioned above, the author believes that de-fog and de-haze are essential for a vision based driver assistance system. Further research should be carried out in order to identify the appropriate method for the proposed driver assistance system.

VI. Image De-noising

The image acquisition of image is usually noisy. It is unable to avoid large amount of noise in the process of image gathering and transmission[26]. So, it is important to apply de-noising algorithms prior to the image processing algorithms.

TABLE II. IMAGE DE-NOISING METHODS

Method	Description
Lifting wavelet transform [26]	Provides better results than traditional image de-noising
Curvelet transform [27]	Represents edges better than wavelets on noisy images. But on noiseless images, the curvelet transform does not provide good results
Novel Decomposition scheme for Image de-noising [28]	Shows improved performance and simpler implementation compared to other approaches based on wavelet, contourlet etc

The image is converted into some domain where the noise component is more easily identified. Then the noise is removed using the thresholding operation[29]. Lifting wavelet transform [26], curvelet transform [27] and Novel Decomposition Scheme for Image De-Noising [28] are some of the methods used for de-noising.

VII. SUMMARY

The problem of image degradation due to poor weather condition is regarded as a major problem in many vision based applications.

The de-weathering methods were categorized into few sections such as interactive de-weathering, de-weathering using multiple images, model based methods, non-model based methods. The author has paid attention on specific de-weathering techniques such as de-rain, de-fog and de-haze. The algorithms used in interactive de-weathering are Dichromatic colour Transfer, De-weathering using depth heuristics and Restoration using planar Depth segments.

Image enhancement methods are categorized into two sections such as non-model based and model based methods. Non model based methods use the information in the image for the processing. Non model based methods are global histogram equalization and adaptive histogram equalization (also known as local histogram equalization), contrast limited adaptive histogram equalization, retinex algorithm and wavelet based methods. The main aim of retinex algorithm is to fill the gap between human vision and machine vision. Many wavelet based methods are available such as weighted average arithmetic (WAA) and Laplacian pyramid transform (LPT). But it is considered that wavelet transform produces better results than WAA and LPT. The main disadvantage of the non-model based methods is the problem with colour fidelity. Model based methods use physical models to predict the pattern of image degradation.

The physics based methods require extra information about the imaging equipment or imaging environment. Interactive de-weathering, de-weathering using multiple images can be considered model based methods.

Moving mask algorithm, fuzzy logic based algorithm, dark channel prior with an iterative algorithm etc are used for removing fog.

Fuzzy logic based algorithm is proposed in order to solve the problems in de-weathering fog degraded images. Mengyang et al., [22] propose a method for defogging using dark channel prior with an iterative algorithm.

Dark channel prior can be used for de-hazing too. The methods explained in interactive de-weathering can also be used for removing haze. But such methods are appropriate for an offline system.

When all the above details are analysed, it is clear that de-weathering using multiple images and interactive de-weathering are not suitable for a driver assistance system. Fully automated (minimum interaction of the user) system is appropriate to provide an efficient service. De-rain should not be included as it requires high computation. De-haze and de-fog are essential features for a driver assistance system. Retinex algorithm is suitable because it is capable of providing a real time performance in de-weathering process. Image de-noising should also be used because the image acquisition is usually noisy.

The "De-weathering" process could be used in other applications such as surveillance systems, terrain classification and underwater investigation too.

REFERENCE

[1] N. Hautiere, et al., "Mitigation of Visibility Loss for Advanced Camera-Based Driver Assistance," IEEE Transactions on Intelligent Transportation Systems, vol. 11, pp. 474-484, 2010.

[2] N. Apostoloff, "Vision based lane tracking using multiple cues and particle filtering," Master of Philosophy, The Australian National University, 2005.

[3] N. Hau, et al., "A Visibility Improvement System for Low Vision Drivers by Nonlinear Enhancement of Fused Visible and Infrared Video," in IEEE Computer Society Conference on Computer Vision and Pattern Recognition - Workshops, 2005. CVPR Workshops., San Diego, CA, USA 2005, pp. 25-25.

[4] S. G. Narasimhan and S. K. Nayar, "Vision and the Atmosphere," Int. J. Comput. Vision, vol. 48, pp. 233-254, 2002.

[5] J. B. Zimmerman, et al., "An evaluation of the effectiveness of adaptive histogram equalization for contrast enhancement," IEEE Transactions on Medical Imaging, vol. 7, pp. 304-312, 1988.

[6] S. G. Narasimhan and S. K. Nayar, "Interactive (De)Weathering of an Image using Physical Models," in IEEE Workshop on Color and Photometric Methods in Computer Vision, In Conjunction with ICCV, 2003, p. 8.

[7] Z. Yuhui, et al., "Image De-Weathering for Road Based on Physical Model," in Information Engineering and Computer Science, 2009. ICIECS 2009. International Conference on, Wuhan 2009, pp. 1-4.

[8] W. Xin and T. Zhenmin, "Automatic image de-weathering using physical model and maximum entropy," in IEEE Cybernetics and Intelligent Systems, Chengdu 2008, pp. 996-1001.

[9] J. John and M. Wilscy, "Enhancement of weather degraded video sequences using wavelet fusion," in 7th IEEE International Conference on Cybernetic Intelligent Systems, London, 2008, pp. 1-6.

[10] Z. Xu, et al., "Colour image enhancement by virtual histogram approach," IEEE Transactions on Consumer Electronics, vol. 56, pp. 704-712, 2010.

[11] S. M. Pizer, et al., "Adaptive histogram equalization and its variations," Computer Vision, Graphics, and Image Processing, vol. 39, pp. 355-368, 1987.

[12] Z. Yi-Shu and L. Xiao-Ming, "An improved fog-degraded image enhancement algorithm," in International Conference on Wavelet Analysis and Pattern Recognition., Beijing 2007, pp. 522-526.

[13] X. Zhiyuan, et al., "Fog Removal from Video Sequences Using Contrast Limited Adaptive Histogram Equalization," in International Conference on Computational Intelligence and Software Engineering, Wuhan 2009, pp. 1-4.

[14] K. R. Joshi and R. S. Kamathe, "Quantification of retinex in enhancement of weather degraded images," in International Conference on Audio, Language and Image Processing., Shanghai 2008, pp. 1229-1233.

[15] E. Wang, et al., "Research on road image fusion enhancement technique based on wavelet transform," in IEEE Vehicle Power and Propulsion Conference., Harbin, 2008, pp. 1-5.

[16] G. D. Hines, et al., "Single-Scale Retinex Using Digital Signal Processors," in Global Signal Processing Expo (GSPx), 2004.

[17] G. Li, et al., "Fusion Enhancement of Color Image Based on Global Histogram Equalization," in International

Conference on Computer Science and Software Engineering, Wuhan, Hubei, 2008, pp. 205-208.
[18] K. Garg and S. K. Nayar, "Vision and Rain," Int. J. Comput. Vision, vol. 75, pp. 3-27, 2007.
[19] P. C. Barnum, et al., "Analysis of Rain and Snow in Frequency Space," Int. J. Comput. Vision, vol. 86, pp. 256-274, 2010.
[20] A. MacCarley, "Advanced Image Sensing Methods for Traffic Surveillance and Detection," University of California, Berkeley,1999.
[21] N. Desai, et al., "A Fuzzy Logic Based Approach to De-Weather Fog-Degraded Images," in Sixth International Conference on Computer Graphics, Imaging and Visualization., 2009, pp. 383-387.
[22] C. Mengyang, et al., "Single image defogging," in IEEE International Conference on Network Infrastructure and Digital Content., Beijing 2009, pp. 675-679.
[23] D. Yong, et al., "Haze detection and removal in high resolution satellite image with wavelet analysis," IEEE Transactions on Geoscience and Remote Sensing, vol. 40, pp. 210-217, 2002.
[24] F. Guo, et al., "Automatic Image Haze Removal Based on Luminance Component," in 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM), Chengdu City, China, 2010, pp. 1-4.
[25] H. Kaiming, et al., "Single image haze removal using dark channel prior," in IEEE Conference on Computer Vision and Pattern Recognition., Miami, FL 2009, pp. 1956-1963.
[26] X. Wang, "Image De-noising Based on Multi-wavelet," in International Forum on Information Technology and Applications., Chengdu 2009, pp. 523-525.
[27] J. L. Starck, et al., "Gray and color image contrast enhancement by the curvelet transform," IEEE Transactions on Image Processing, vol. 12, pp. 706-717, 2003.
[28] R. C. Bilcu and M. Vehvilainen, "A Novel Decomposition Scheme for Image De-Noising," in IEEE International Conference on Acoustics, Speech and Signal Processing., Honolulu, HI, 2007, pp. I-577-I-580.
[29] P. Kovesi. (2007, 23 January). Phase Preserving Denoising of Images. Available: http://www.csse.uwa.edu.au/~pk/research/pkpapers/denoise.pdf