A REVIEW ON ANALYSIS OF THE ATMOSPHERIC VISIBILITY RESTORATION AND FOG ATTENUATION USING GRAY SCALE IMAGE

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ABSTRACT

One of the central problems in image processing in open-air is the presence of cloud, vapor, fog or smoke which fades the colors and reduces the contrast of the observed things. A novel algorithm and variants is proposed for visibility restoration from a single picture. The main advantage of the proposed algorithm compared with other is its speed: its intricacy 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 symbol, lane-marking and impediment uncovering from an in-vehicle camera. Another advantage is the prospect to handle both color images and gray level images since the ambiguity between the presence of fog and the objects with low color dispersion is solved by assuming only small objects can have colors with low saturation. The algorithm is controlled only by a few parameters and consists in: atmospheric veil inference, image restoration and smoothing, tone mapping. A comparative study and quantitative evaluation is proposed with a few other state of the art algorithms which demonstrate that similar or better quality results are obtained. Finally, an application is presented to lane-marking extraction in gray level images, illustrating the interest of the approach.

Keywords: Color Distortion, fog, Hazy, pixels, visibility restoration.

I. INTRODUCTION

Pictures of outside sight commonly include haze, fog, or other types of atmospheric dreadful conditions caused by particles in the atmospheric medium absorbing and spreading light as it travels from the source to the observer. Many vision algorithms rely on the assumption that the input image is precisely the scene radiance, i.e. there is no interruption from haze. [2] When this assumption is violated, algorithmic errors can be catastrophic. One could easily see how a car navigation system that did not take this effect into account could have dangerous consequences. An effective method for fog removal is an ongoing area of interest in the image processing and computer vision fields.

In-vehicle vision system should take haze effects into account to be more reliable. Solution for this is to adjust the operating thresholds of the system or to shortly immobilize it if these thresholds have been surpassed. Next solution is that to take away weather effects from the image in advance. Regrettably, the effects vary across the scene. They are exponential with respect to the depth of scene points. Consequently, space-invariant filtering techniques cannot be directly used to adequately remove weather effects from images. A judicious approach is to detect and characterize weather conditions to estimate the decay in the image and then to remove it.

Methods that restore image contrast under bad weather conditions are encountered more often in the literature. Unfortunately, they all have constraints that are too strong to be used onboard a moving vehicle using images that are taken at different times or using images with different polarizing filters.[5] Recently, different methods have been proposed that rely only on a single image as the input. First estimates the weather conditions and approximates a 3-D geometrical model of the scene, which is given a priori and refined during the restoration process. The method is dedicated to in-vehicle applications. The key point is to optimize the scene model. In image contrasts are restored by maximizing the contrasts of the direct transmission while assuming a smooth layer of air light. The method may produce halos near depth discontinuities.[7] Estimates the transmission in hazy scenes, relying on the assumption that the transmission and the surface shading are locally uncorrelated. The method uses a local window-based operation and a graphical model. Despite their good-looking results, these methods solve the problem using optimization algorithms. The problem of these methods is that the depth map that is produced by their atmospheric veil inference may be erroneous due to the ambiguity between white objects and fog.

Another method was proposed which is based on the **use** of [10] color picture with pixels having a hue different from gray. A difficulty with this approach, for the applications we focus on, is that a large part of the image corresponds to the road which is gray and white. Moreover, in many intelligent vehicle applications, only gray-level images are processed.

Visibility improvement algorithms [12] were proposed working from a single gray-level or color image without using any other extra source of information. These algorithms rely on a local spatial regularization to solve the problem. Being local, these algorithms can cope with homogeneous and heterogeneous fog. The main drawback of the algorithms is their processing time: 5 to 7 minutes and 10 to 20 seconds on a 600 X 400 image, respectively. The algorithm proposed is much sooner with a processing time of 0.2 second on a Dual-Core PC on similar image size.[6] The drawback of these three visibility enhancement methods, and of the other variants or enhanced algorithms more recently proposed, is that they are not dedicated to road images and thus the road part of the image which is gray may be over-enhanced. This is due to the ambiguity between light colored objects and the presence of fog, and leads to the apparition of undesirable structures in the enhanced image.

The most important property of a road image is that a large part of the image corresponds to the road way which can reasonably be assumed to be planar. [15] Visibility enhancement dedicated to planar surface, but this algorithm is not able to correctly enhance visibility of objects out of the road plane. Recently, a visibility enhancement algorithm dedicated to road images was proposed which was also able to enhance contrast for objects out of the road plane. This algorithm makes good use of the planar road assumption but relies on an homogeneous fog assumption. The important property of a road image is that a large part of the image corresponds to the road way which can reasonably be assumed to be planar. [18] Visibility enhancement dedicated to planar surface was first proposed in, but this algorithm is not able to correctly enhance visibility of objects out of the road plane. Recently, a visibility enhancement algorithm dedicated to road images was proposed which was also able to enhance contrast for objects out of the road plane. This algorithm makes good use of the planar road assumption but relies on an homogeneous fog assumption.

III. EFFECTS OF FOG

Assuming an object of intrinsic luminance L0 (u,v), its apparent luminance L(u,v) in attendance of a fog of extinction coefficient k is modeled by Koschmieder's law [11]

L(u,v)=L0 (u,v) e-kd(u,v) +Ls (1- e-kd(u,v))

Where d(u,v) is the distance of the object at pixel (u,v) and Ls is the luminance of the sky. As described by (1), fog has two special effects: first an exponential decay e-kd(u,v) of the intrinsic luminance L0 (u,v), and second the addition of the luminance of the atmospheric veil Ls (1 - e-kd(u,v)) which is an growing function of the object distance d(u,v). These two effects can be seen on the same scene in Fig. 2 for different values of k. The meteorological visibility distance is defined as dm =-(ln(0.05))/(k), see [11]. From now on, we suppose that the camera response is linear, and thus image intensity I is substituted to luminance L.

IV. HALO EFFECTS

According to [10], the recovered image may become oversaturated when the dark channel prior uses a small patch size. For this reasons, He et al. adopt a patch size of 15 X 15 to keep away from oversaturation of recovered images. However, using a patch size of 15 X 15 in the dark channel prior will cause the recovered image to contain halo artifacts along depth discontinuities. As a result, He et al. apply the soft matting technique to purify the transmission map and diminish the propensity for generation of halo effects in the recovered image. Color Distortion: In their previous study, He et al [2]. Recommend a haze removal technique to recover the original scene radiance by using the same restoration for each color channel. It is assumed that each color channel of the input image has a equivalent distribution in its RGB color histogram. Nonetheless, different regions of the world have diverse weather conditions, which may lead to serious color distortion problems in captured images. For a case, a sandstorm in the Beijing area results in the blue hue of the spectrum becoming largely absorbed by atmospheric particles. This will lead to a captured image featuring prominent yellow and orange h aze. Thus, the captured sandstorm images will always have different color distributions in their RGB color histograms. However, the dark channel prior assumes that the color channel of the input image has a similar histogram distribution under different conditions, such as fog. By contrast, the histogram distribution of color channels in a foggy scene is different than in sandstorm environments. Consequently, the recovered images will still have a serious color distortion problem due to using the same restoration for all color channel.

C) Insufficient Transmission Map Estimation: The foremost principle of the haze elimination technique of [10] is predicated upon using the dark channel prior to estimate the transmission map, which in turn depends on the least amount value of the RGB color channel in the input image. Fundamentally, a lower intensity of the dark channel signifies thinner haze in the corresponding area; on the other hand, a higher intensity in the dark channel signifies thicker haze. However, in the sandstorm image, the blue hue of the spectrum is largely absorbed by atmospheric particles and the histogram of the dark channel prior is very close in shape to the histogram of the blue channel. For this reason, the dark channel prior based on a smallest amount operator usually shows lower intensity in sandstorm images due to the lessened intensity of the blue channel. Thus, in images of major sandstorms, the dark channel prior method will often perceive less haze than that which actually exists. The lack of blue in the spectrum causes the erroneous judgment of dark channel prior.

V. COLOR AND CONTRAST ENHANCEMENT

We now recall the [19] Multiscale Retinex (MSR) and Contrast limited adaptive histogram equalization (CLAHE) algorithms. These two algorithms are not based on Koschmieder’s law (1) and thus are only able to remove a fog of constant thickness on an image. They are not visibility enhancement algorithms. However, we found it interesting to include these two algorithms in our comparison in order to verify that visibility enhancement algorithms achieve better results.

VI. MULTISCALE RETINEX (MSR)

The multiscale retinex (MSR) is a non-linear image enhancement algorithm proposed by [10]. The overall impact is to brighten up areas of poor contrast/brightness but not at the expense of saturating areas of good contrast/brightness. The MSR output is simply the weighted sum of the outputs of several single scale retinex (SSR) at different scales. Each color component being processed independently, the basic form of the SSR for on input image I (u,v) is:

Rk (u,v) = logI (u,v) - log[Fk (u,v) * I (u,v)],

where Rk (u,v) is the SSR output, Fk represents the kth surround function, and) is the convolution operator. The surround functions, Fk are given as normalized Gaussians:

F k(u,v) =Kk e-(u2-v2)\ v2k

where vk is the scale controlling the extent of the surround and lk is for unit normalization. Finally the MSR output is: R(u,v)=∑ WkRk(u,v)

where Wk is the weight associated to Fk . The number of scales used for the MSR is, of course, application dependent. We have tested different sets of parameters, and we did not find a better parameterization than the one proposed by [10]. It consists of three scales representing narrow, medium, and wide surrounds that are sufficient to provide both dynamic range compression and tonal rendition: K = 3, v1 = 15, v2 = 80, v3 = 250, and Wk = 1/3 for k = 1, 2, 3. Results obtained using the multiple retinex on three foggy images are presented in column two

VII. CONTRAST-LIMITED ADAPTIVE HISTOGRAM EQUALIZATION (CLAHE)

Contrast-Limited Adaptive Histogram Equalization (CLAHE) [3] locally enhances the image contrast. As proposed in, CLAHE operates on 8 X 8 regions in the image, called tiles, rather than the entire image. Each tile’s contrast is enhanced, so that the histogram of the output region approximately matches a flat histogram. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The enhanced contrast, especially in homogeneous areas, is limited to avoid amplifying noise or unwelcome structures, such as object textures, that might be present in the image. The parameter controlling this limitation was optimized on 40 images, varying both the scene and the fog properties. Results obtained using the CLAHE algorithm is presented.

VIII. FREE-SPACE AREA DETECTION

The inconvenience of the flat-world restoration can be turned into our advantage. Indeed, by detecting the pixels whose intensity is null after contrast restoration for c = cmin, we can very easily extract the free space in front of the vehicle accordingly by looking for the biggest connected component in front of the vehicle. This region is denoted D. To improve the results of this last step, a morphological opening of the connected component is performed. The segmented region Scmin , corresponding to the vertical objects, is overlaid in red, and the segmented free-space region D is overlaid in green. The proposed method allows obtaining quite good results, even if some minor improvements could be made on the segmentation of curbs and very bright objects. The quality of these results can be compared with color-based or stereovision approaches [14]. The good point in our method is that we only use one gray-level image. However, it only works in daytime foggy weather. The classical methods and the proposed one are, thus, complementary. Second, we can take advantage of this segmentation to compute a 3-D model of the environment. This is the topic of Section IV-D.

IX. ASSESSMENT METHODS

To evaluate visibility enhancement algorithms,[18] we need images of the same scene with and without fog. However, obtaining such pairs of images is extremely difficult in practice since it requires to check that the illumination conditions are the same into the scene with and without fog. As a consequence, for the evaluation of the proposed visibility enhancement algorithm and its comparison with existing algorithms, we build up two sets of images without fog and with synthetic fog, from 66 synthetic and 10 camera scenes.

To assess the performance of our method, we first propose a methodology to quantitatively evaluate the restoration. We then analyze the sensitivity of the method to the fog input parameters and the method internal parameters. Finally, we analyze the performance of the method by looking at the computation time and by comparing our method with current state-of-theart methods.

In this section, we propose a novel visibility restoration approach in order to restore hazy images captured during inclement weather conditions such as haze, fog, sandstorms, and so on.

Our approach involves three important modules: [14] 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 which 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.

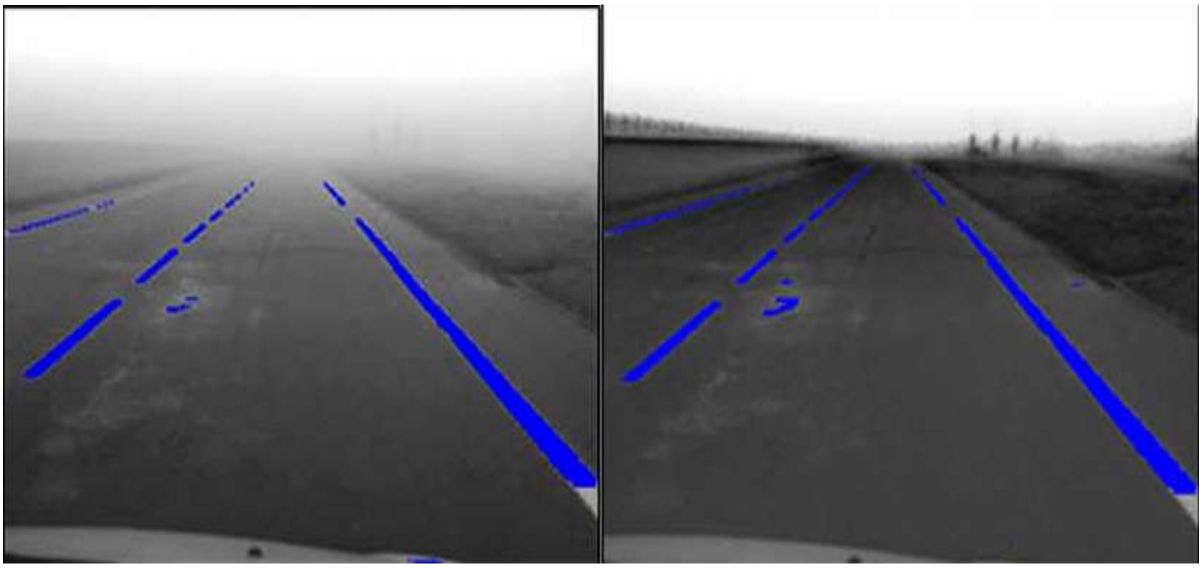
X. APPLICATIONS

Here, we propose some applications of the proposed [16] contrast restoration algorithm: improvement of road-marking feature extraction, improvement of camera-based obstacle detection, and improvement of circular road-sign detection. Indeed, these applications rely on gradient computation.

10.1 Road-Marking Feature Extraction

Road-marking detection is a fundamental task to develop camera-based driving assistances, which aims at avoiding road departure. Road-marking feature extraction is the low-level processing of the road-marking detection. A comparison of the different existing algorithms has been proposed in [14].

According to the paper, the symmetrical local threshold filter gives the best results. We applied this filter to the image given in Fig. and the restored version of this image given in Fig. with the same settings of the filter. We can see an improvement of the detection range of the road markings. Using the same images in Section V-C1, the receiver operating characteristic (ROC) curves were computed without restoration and with our algorithm and the algorithms of Tan, He et al.,



B. Road-Sign Feature Extraction

In the same way, the detection of road signs may be improved. Indeed, most approaches rely on symmetry detectors, like the approach proposed in [2], and could benefit from contrast improvement in the images. Based on a similar approach proposed in [6], shows the detection of circular signs using a foggy image and a restored image. Due to the restoration, five signs have been found, whereas none of them has been found using the original image. The parameters of the detection method are the same in both cases and set to typical daytime values.

C. Road Obstacle Detection

A review of existing methods for camera-based road obstacle detection has been proposed in [18]. Weather conditions reduce the operation range of most methods. Consequently, contrast restoration may, of course, improve the operation range of these methods. For example, corner extraction, gradient extraction, and texture classification are improved. On the other side, the flat-world-restoration method presented in Section IV-B is able to segment all vertical objects, among which are the road obstacles. By merging the output of this algorithm with existing obstacle-detection techniques, road-obstacle detection in daylight fog may be largely improved.

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