A Critical Study and Comparative Analysis of Various Haze Removal Techniques

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ABSTRACT
Fog is just a combination of two parts airlight and direct attenuation; it reduces the image quality and produces big quantity of problems in video monitoring, monitoring and navigation. Therefore, to eliminate it from an image, several defogging methods have been planned in literature. Defogging may be performed applying different photos and single image haze treatment strategy. That paper presents a review on the different haze treatment methods. These methods are generally utilized in several programs for instance outdoor monitoring, subject detection, electronic devices etc. The overall objective with this paper has gone to investigate the different practices for efficiently eliminating the haze from digital images. It's been explored that nearly all the prevailing researchers have neglected several dilemmas; i.e. no approach is exact for various kind of circumstances.

General Terms
Critical study for various haze removal techniques

Keywords
Visibility Restoration, Fog Removal, Dark Channel Prior.

1. INTRODUCTION
Visibility restoration [1] refers to different ways that help to reduce and remove the degradation which occurs when a digital image is taken. The image suffers from degradation due to various reasons such as relative object-camera motion, blur due to camera misfocus, relative atmospheric turbulence etc. The main cause of image degradation is due to bad weather conditions such as fog, haze, rain and snow . During Fog, when we take an image using a camera then the light gets scattered before reaching the camera due to some impurities in the atmosphere. Due to this, automatic monitoring system, outdoor recognition system and intelligent transportation system are badly affected. Scattering of light is caused by two fundamental phenomena such as attenuation and airlight. By using haze removal algorithms, we can enhance the stability and robustness of the visual system. Removal of haze is a difficult task because fog depends upon the unknown scene depth information. Fog effect is defined as event of distance between camera and object. Hence removal of fog requires the estimation of airlight map or depth map. The haze removal techniques can be classified into two categories: image enhancement and image restoration. Image enhancement doesn't include the reason why fog degrades image quality. This technique enhances the contrast of haze image but it leads to loss of information in image.

Fig 1[(13)]: (a) Original image (b) Processed image

Image restoration studies the physical procedure of imaging in fog. After observing degradation style of fog, image will undoubtedly be established. At last, the degradation process is used to produce the fog free image.

2. VISIBILITY RESTORATION TECHNIQUES
Various image restoration techniques are as follows:

2.1 Dark channel prior
Dark channel prior [3] has been developed to estimate atmospheric light in the dehazed image so as to produce the output image. This technique is basically used for non-sky patches, as at least one color channel has surprisingly low intensity at some pixels. The intensity is reduced due to three components:-

- Colourful items or surfaces(green grass, tree, blooms and so on)
- Shadows(shadows of car, buildings etc)
- Dark items or surfaces(dark tree trunk, stone)

Since the outdoor images are usually filled with shadows and colors, the dark channels of these images also become dark. Due to this, fog (airlight), a haze image is brighter than its image without haze. Thus, dark channel of haze image has higher intensity in region with higher haze. So, intensity of dark channel is a rough approximation of the thickness of haze. In dark channel prior we can also use pre and post processing steps for recovering results. In post processing we can use soft matting or bilateral filtering etc. Let J(x) be an input image, I(x) is foggy image, t(x) could be the transmission of the medium. The attenuation of image due to fog can be expressed as:

$$I_{att}(x) = J(x)t(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

the effect of fog IS Airlight effect and it is expressed as:

$$I_{airlight}(x) = A(1 - t(x)) \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Dark channel for an arbitrary image J, expressed as J dark is defined as:

$$J^{dark}(x) = \frac{min}{y \in \Omega(x)} (\min J^{C}(Y)) \ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Figure 2.a([3]) Haze removal : Input Haze Image

Figure 2.b([3]) Haze removal :Restored Hazefree Image

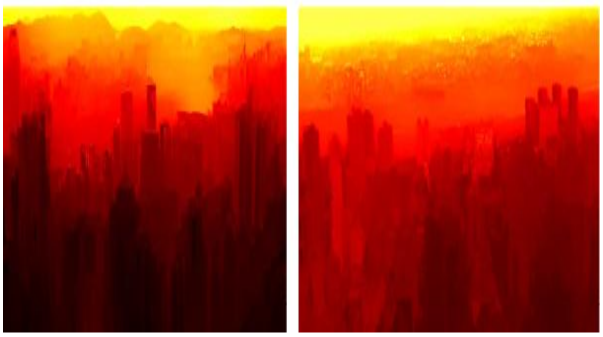

Figure2.c:Haze removal results([3])Top: input haze images. Middle: restored haze-free images. Bottom: depth maps.

In this J^c s the color image comprising of RGB components, represents a nearby patch which has its origin at x. The reduced intensity of dark channels is attributed mainly due to shadows in images, saturated color objects and dark objects in images. After dark channel prior, we have estimated transmission t(x) for proceeding further with the solution. Another assumption needed is that let Atmospheric light A is also known. (4) is normalized by dividing both sides by A:

$$\frac{I^c}{A^c}(x) = t(x)\frac{J^c}{A^c}(x) + 1\text{-}t(x) \ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

2.2 Clahe

Contrast limited adaptive histogram equalization CLAHE [1] does not want any predicted weather information for the processing of hazed image. Firstly, the image is captured by the camera in foggy condition and then converted from RGB (red, green and blue) color space to HSI (hue, saturation and intensity) color space. The images are converted because the human sense colors similarly as HSI represent colors. Secondly intensity component is processed by CLAHE without affecting hue and saturation. This process use histogram equalization on a contextual region. Firstly, histogram is clipped and the clipped pixels are redistributed to each gray-level. In this each pixel intensity is shortened to maxima of user selectable. Finally, the image processed in HSI color space is converted back to RGB color space.

It is a generalization of Adaptive Histogram Equalization (AHE). CLAHE differs from ordinary AHE in its contrast limiting. CLAHE limits the amplification by clipping the histogram at a user-defined value called clip limit. The clipping level determines how much noise in the histogram should be smoothed and hence how much the contrast should be enhanced. A variation of the contrast limited technique called adaptive histogram clip (AHC) can also be applied. AHC automatically adjusts clipping level and moderates over-enhancement of background regions of images. One of the AHC that normally used is Rayleigh distribution which produces a bell-shaped histogram.

Figure 3 resultant image using CLAHE method([1]): (a) input image(b) output image

The function is given by

$$\text{Rayleigh}_g = g_{min} + [2\alpha^2 \ln(\frac{1}{1 - P(f)})]^{0.5} \ldots\ldots \text{(5)}$$

where g_{min} is a minimum pixel value, P(f) is a cumulative probability distribution and α is a nonnegative real scalar specifying a distribution parameter. In this study, clip limit is set to 0:01 and α value in Rayleigh distribution function is set to 0:04.

2.3 Wiener filtering

Wiener filtering is based on dark channel prior: Wiener filtering [5] is used to counter the issues such as color distortion while using dark channel prior when the images with large white area is processed. When using dark channel prior the worth of media function is rough which create halo effect in final image. So, median filtering is employed to estimate the media function, so that edges can be preserved. After making the median function more accurate it's along with wiener filtering so that the image restoration problem is transformed into optimization problem. This algorithm is used to recover the contrast of a large white area for image. The running time of image algorithm is also less.

2.4 Bilateral filtering

Bilateral Filtering [2] smoothes images while preserving edges, by means of a non-linear mixture of nearby image values. In this, filter replaces each pixel by weighted averages of its neighbour's pixel. The weight given to each neighbour pixel decreases with both the distance in the image plane and the distance on the intensity axis. This filter produces faster results. While using the bilateral filter we can use pre-processing and post processing steps for better results. Histogram equalization is used as pre-processing and histogram stretching as an article processing. These steps help to improve the contrast of image before and after usage of bilateral filter. This algorithm is independent of density of fog thus,it works on on the images taken in dense fog. It generally does not require user intervention. It is applicable in tracking and navigation, consumer electronics and entertainment industries.

Figure 4 Weiner defogged image([5]): (a) Original foggy image (b) Defogged image (c) Weiner defogged image

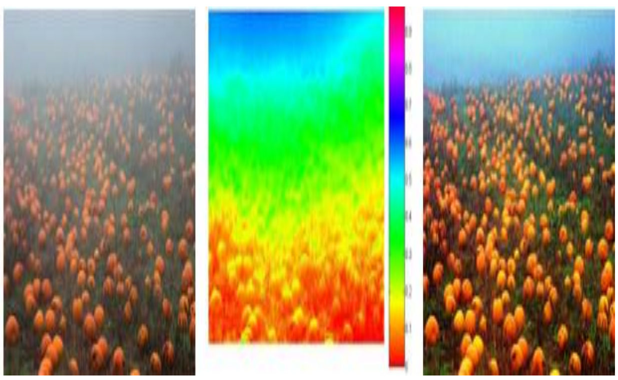

Figure 5 Image filtering using bilateral filter ([2]): (a) original foggy 'pumpkins' image, (b) corresponding air light map using bilateral filter, and (c) Restored image

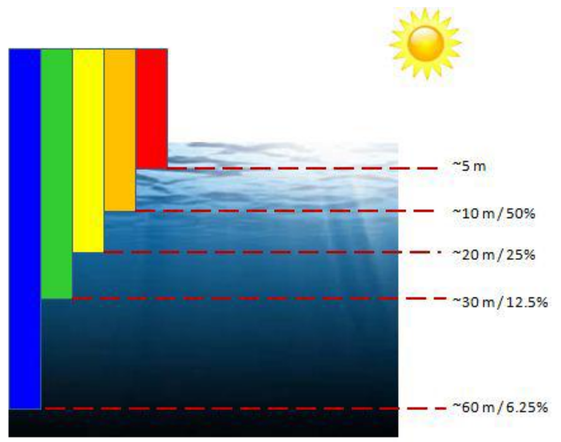

Figure 6: Absorption of light by water ([12])

Figure 6 shows an illustration about the absorption of light

2.5 Mix-CLAHE

Hitam et al. (2013) [15] presented method to improve contrast of underwater images by using a mixture Contrast Limited Adaptive Histogram Equalization. The enhancement method enhances the visibility of underwater images and produces the best MSE and the PSNR values. Thus, it proves that the mix-CLAHE based method is promising for classifying coral reefs particularly when visual cues are visible.

The proposed CLAHE-Mix first normalize the result of CLAHE-RGB

$$RGB_n = [\sqrt{r_{c_1}^2 + r_{c_2}^2}, \sqrt{g_{c_1}^2 + g_{c_2}^2}, \sqrt{b_{c_1}^2 + b_{c_2}^2}] \ldots\ldots(6)$$

Conversion of RGB to HSV and HSV to RGB is shown by above variables.

by water. For each 10m increase in depth the brightness of sunlight will drop by half. The majority of red light is fully gone by 50% from the outer lining but blue continues to great depth. That's why most underwater images are dominated by blue-green coloration. CLAHE-Mix first normalizes caused by CLAHE-RGB.

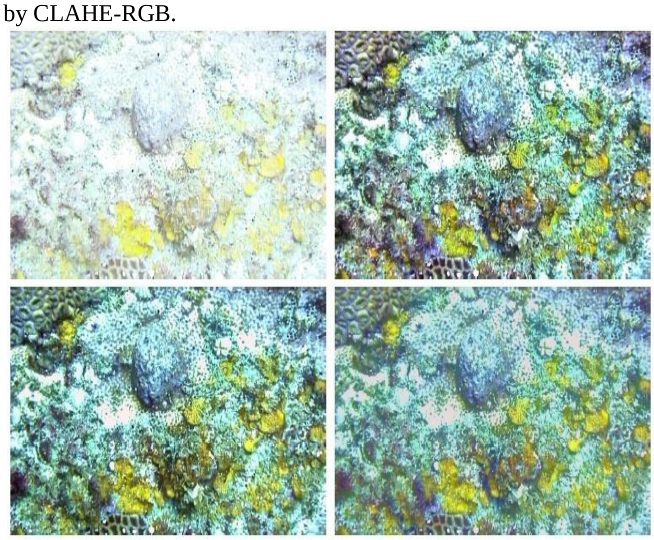

Figure 7: Comparison of CLAHE methods on image([12]). Upper left: original underwater image. Upper right: CLAHE-RGB image. Bottom left: CLAHE-HSV image. Bottom right: CLAHE-Mix image.

3. COMPARATIVE ANALYSIS TABLE

Table 1 shows the comparison of the various haze removal techniques.

Table 1: Comparison of various haze removal techniques

S. NO.	AUTHORS	YEAR	TECHNIQUES	FEATURES	LIMITATIONS
[1]	Xu, Zhiyuan, Xiaoming Liu, and Na Ji [IEEE]	2009	Contrast Limited Adaptive Histogram Equalization	Effective in comparison with traditional methods	Neglected the techniques to reduce the noise issue
[2]	Tripathi, A. K., and S. Mukhopadhyay [IEEE]	2012	fog removal algorithm bilateral filter	independent of the density of fog and does not require user intervention	Not much effort has focused on the integrated approach of the AHE and ACO
[3]	Wang, Yan, and Bo Wu [IEEE]	2010	local dark channel prior	obtain more accurate result	The problem of the uneven illuminate is also neglected
[4]	Yu, Jing, and Qingmin Liao [IEEE]	2011	atmospheric scattering model	achieves good restoration for contrast and color fidelity	Neglected the techniques to reduce the noise issue
[5]	Shuai, Yanjuan, Rui Liu, and Wenzhang He[IEEE]	2012	wiener filtering based on dark channel prior	shortens the running time	The problem of the uneven illuminate is also neglected
[6]	Cheng, F-C., C-H. Lin, and J-L. Lin	2012	lowest level channel prior	utilises the exact $O(1)$ bilateral filter for high performance	The problem of the uneven illuminate is also neglected
[7]	Xu, Haoran [IEEE]	2012	fast bilateral filtering combined with dark colors prior	improve the adaptability and fast execution speed	Neglected the techniques to reduce the noise issue
[8]	Sahu, Jyoti [International journal2]	2012	color image contrast Fog removing algorithm	efficient and reliable choice for fog removing	The problem of the uneven illuminate is also neglected
[9]	Matlin, Erik, and PeymanMilanfar	2012	iterative, adaptive, non-parametric regression method.	denoise the image	The problem of the uneven illuminate is also neglected
[10]	Kang, Li-Wei, Chia-Wen Lin, and Yu-Hsiang Fu. [IEEE]	2012	single-image-based rain removal framework	preserves most original image details	Neglected the techniques to reduce the noise issue
[11]	Yuk, Jacky Shun-Cho, and Kwan-Yee Kenneth Wong	2012	foreground decremental preconditioned conjugate gradient	effectively improve the visualization quality	The problem of the uneven illuminate is also neglected
[12]	Hitam, M. S., W. N. J. H. W. Yussof, E. A. Awalludin, and Z. Bachok	2013	mixture Contrast Limited Adaptive Histogram Equalization	improves the visual quality of underwater images	The problem of the uneven illuminate is also neglected
[21]	Huang, Darong, Zhou Fang, Ling Zhao, and Xiaoyan Chu.	2014	dark channel prior	restore the fogging image effectively and reduce the time	Neglected the techniques to reduce the noise issue

				complexity	
[22]	Ghani, Ahmad Shahrizan Abdul, and Nor Ashidi Mat Isa.	2015	Rayleigh distribution	enhances the image contrast, reduces the blue-green effect, and minimizes under- and over-enhanced areas in the output image	The problem of the uneven illuminate is also neglected
[23]	Wang, Jin-Bao, Ning He, Lu-Lu Zhang, and Ke Lu.	2015	dark channel prior	improve the operational efficiency	Neglected the techniques to reduce the noise issue

4. CONCLUSION AND FUTURE WORK

Fog removal formulas are more helpful for various vision applications. It can be found that many the existing scientific study has neglected alot of issues; i.e. no technique is precise for different circumstances. The review has demonstrated the undeniable fact that shown methods have neglected the methods to reduce the noise concern which can be shown within the output images of the last haze removal algorithms. The issue of uneven and also over illumination may also be an issue for dehazing methods. So it will be expected to change the prevailing methods in this manner that altered strategy may continue steadily to function better. In near future, to eliminate the issues of present research a different integrated algorithm is going to be proposed.

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