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Review Article

A Review on Various Haze Removal Techniques for Image Processing

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Abstract

In this review paper, we have presented and compared a study of various fog/haze removal algorithms/techniques for image processing. Many algorithms are proposed so far for efficient fog removal. The dark channel prior based fog removal has provided quite promising results over the available techniques. Many researchers have also proposed various improvements in the dark channel prior so far to get better results. The joint trilateral filter based approach has shown more significant results over the available techniques. The overall objective of this review paper is to explore the short comings of the earlier presented techniques used in the revolutionary era of image processing applications.

Keywords: *Haze, Dark channel prior, Fog removal, Joint trilateral filter, CLAHE, MIX-CLAHE etc.*

1. Introduction

Visibility restoration (Xu, Zhiyuan *et al*, 2009) refers to different methods that aim to reduce or remove the deterioration or degradation that have occurred while the digital image was being obtained. The deterioration may be due to various factors like relative object-camera motion, blur due to camera misfocus, relative atmospheric violent features and others. In this we will be discussing about the degradations due to bad weather such as fog, haze in an image. The image quality of outdoor scene in the fog and haze weather condition is usually deteriorated by the scattering of a light before reaching the camera due to these large quantities of suspended particles (e.g. fog, haze, smoke, impurities) present in the atmosphere. This occurrence influences the normal work of automatic (mechanized) monitoring system, outdoor recognition system and smart transportation system. Scattering is caused by two basic phenomena such as attenuation and airlight. By the usage of effective haze or fog removal of image, we can improve the stability and robustness of the visual system. Haze removal is a difficult task because fog depends on the unknown scene depth map information. Fog effect is the result of distance between camera and object. Hence removal of fog requires the estimation of airlight map or depth map.

The current haze removal method can be divided into two categories: (a) image enhancement and (b) image restoration. This method can enhance the contrast of haze image but loses some of the information about image.

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(a) (b)

Fig 1 (a) Original image (b) Processed image

2. Literature Survey

This section covers the literature from the study of various research papers. Wang, *et al*. (2010) has explored that haze removal from the image depend upon the unknown depth information. This algorithm is based on the atmospheric scattering physics-based model. In this on selected region a dark channel prior is applied to obtain a novel estimation of atmospheric light. This model is based upon some observation on haze free outdoor image. In non-sky patches, at least one color channel has very low intensity at some pixels. The low intensity in that region is due to shadows, colorful objects and dark objects etc.

Yu, *et al*. (2011) has proposed a novel fast defogging method from a single image based on the scattering model. A white balancing is used prior to the scattering model applied for visibility restoration. Then an edge-preserving smoothing approach based on weighted least squares (WLS) optimization framework to smooth the edges of image. At last inverse scene albedo is applied for recovery process. This method does not require prior information.

Shuai, *et al*. (2012) discussed problems regarding the dark channel prior of color distortion problem for some light white bright area in image. An algorithm to estimate the media function in the use of median filtering based on the dark channel was proposed. After making media function more accurate a wiener filtering is applied. By this fog restoration problem is converted into an optimization problem and by minimizing mean square error a clearer, finally fog free image is obtained. This algorithm can make hazed image more detailed, the contour smoother and clearer as compare to dark channel prior. This method is a recovery method, which is a combination of statistical characteristics of the function and noise.

Cheng, *et al*. (2012) has proposed a lowest channel prior for image fog removal. This algorithm is simplified from dark channel prior. It is based on a key fact that fog-free intensity in a color image is usually a least value of trichromatic channels. In dark channel prior to estimate the transmission model it performs as a minimum filter for lowest intensity. This filter leads to halo artifacts, especially in the neighborhood of edge pixels. In this algorithm instead of minimum filter they utilises exact O(1) trilateral filter based on the raised cosines function to the weight value of neighbour to get fog-free image. The quality of the output image and the computation cost of the removal of fog procedure are improved by the trilateral filter used in this algorithm.

Xu, *et al*. (2012) has recommended a model based on the physical process of imaging in foggy weather. In this model a fast haze removal algorithm which is based on a fast trilateral filtering with dark colors prior is explained. Firstly, the atmospheric scattering model is used for to describe the formation of haze image. Then an estimated transmission map is formed using dark channel prior. Then it is combined with gray scale to extract the refined transmission map by using fast trilateral filter instead of soft matting. The reason why the image is dim after the use of dark channel prior is observed and a better transmission map formula is proposed to effectively restore the color and contrast of the image, leading to improvement in the visual effects of image.

Sahu, *et al*. (2012) has proposed an algorithm of fog removal from the color image and also useful in hue preserving contrast enhancement of color images. In this method firstly, the original image is converted from RGB to YCbCr (a way of encoding RGB information). Y′ is the luma component and C_B and C_R are the blue-difference and red-difference chroma components. Secondly, the intensity component of the converted image and the key observation of all the pixels of image are computed.

Matlin, *et al*. (2012) has discussed in this paper a method in which noise is included in the image model for haze formation. All images contain some amount of noise due to measurement error. A specific denoising algorithm known as Block matching and 3D filtering which has used a block matching and collaborative Wiener filtering scheme for removal of noise is used. After pre-processing step this algorithm is divided into two steps a haze estimation step and haze restoration step. Dark channel prior is used for haze estimation. At last image is restored in last step. In some cases when first step of denoising is not successful then a Simultaneous Denoising and Dehazing via Iterative Kernel Regression is used.

Kang, *et al*. (2012) has proposed a single image based rain removal frame work by properly formulating rain removal as an image decomposition problem based on MCA (morphological component analysis). It is a new method which allows us to separate features contained in an image when these features present different morphological aspect. Before applying a proposed method the image is decomposed into the low and high-frequency parts using a trilateral filter. By using sparse coding and dictionary learning algorithms the high frequency part is decomposed into rain component and non-rain component. Sparse coding is a technique of finding a sparse representation for a signal with a small number of nonzero or significant coefficients corresponding to the atoms in a dictionary. The dictionary learning of the proposed method is fully automatic and self-contained where no extra training samples are required in the dictionary learning stage.

Yuk, *et al*. (2012) has proposed a novel Foreground Decremental Preconditioned Conjugate Gradient (FDPCG) for adaptive background defogging of surveillance videos. In this method first of all dark channel prior or soft matting is used for the estimation of map. Then, each background-defogged frame is then processed by background/foreground segmentation algorithm. The transmissions on foreground regions are recovered by the proposed fusion technique first. Then, transmission refinement by the proposed foreground incremental preconditioned conjugate gradient (FIPCG). The proposed method can effectively improve the visualization quality of videos under heavy fog and snowing weather.

Tarel, *et al*. (2012) has recommended a model in this paper for improving road images by introducing an extra constraint taking into account that a large part of the image can be assumed to be a planar road. Enhancement of image is based upon Koschmieder's law. This law is related to the apparent contrast of an object against a sky background, at a given distance of observation, to the inherent contrast and to the atmospheric transmissivity which is assumed to be uniform.

Yeh, *et al.* (2012) has proposed a pixel-based dark/bright channel prior and fog density estimate method for dehazing process. Firstly estimation of atmospheric light is done to observe the effect of light. Then transmission map is used for estimation. Here two methods are used. A pixel-based dark/bright channel prior is used first. After that fog density estimation method is used to estimate fog for removal process. Then trilateral filter is used for refining the transmission map.

Tripathi, *et al*. (2012) has studied that fog formation is due to airlight and attenuation. Airlight increases the whiteness and attenuation increases the contrast in the scene. So a method is proposed which use trilateral filter to recover scene contrast and for the estimation of light. The proposed algorithm does not depend upon the density of fog and does not require user interference. It can handle both color and gray images. Histogram stretching is used as post processing for increasing the contrast of fog removed image. In this generated airlight map does not affect the edges and perform smoothing over the object region. As the algorithm is independent of density of fog present in image so it also performs better for image taken in heavy fog so, it can be widely used as a pre processing step for various computer vision algorithms which use feature information such as object detection, recognition, tracking and segmentation.

Hitam *et al*. (2013) has discussed that the within the last decades, enhancing the quality of an underwater image has received considerable attention due to poor visibility of the image which is caused by physical properties of the water medium.

Hitam *et al*. (2013) has presented a new method called mixture Contrast Limited Adaptive Histogram Equalization (CLAHE) color models that specifically developed for under water image enhancement. The technique operates CLAHE on RGB and HSV color models and both results are combined together using Euclidean norm.

Seiichi Serikawaand Lu (2014) has discussed that Underwater vision has become important issue in ocean engineering. Capturing images underwater has complicated, frequently due to attenuation that is caused by light that is reflected from a surface and is deflected and spreaded by particles, and as simulation significantly decreases the light energy. There have been many methods to renovate and improve the underwater images.

S Serikawa and Lu(2014 proposed a easy prior based on the distinction in attenuation among the diverse color channels, which inspired to guess the transmission depth map through red color channel in underwater digital images. Balance the attenuation inconsistency along the distribution path, and to take the joint trilateral filter for filtering the transmission depth map.

3. Gaps in Literature Survey

Fog removal algorithms become more beneficial for numerous vision applications. It has been originated that the most of the existing research have mistreated many subjects. Following are the different research gaps concluded using the literature survey:

1. The presented methods have neglected the techniques to reduce the noise issue which is presented in the output images of the existing fog removal algorithms.
2. Not much effort has focused on the integrated approach of the Adaptive histogram equalization and Dark channel prior.
3. The problem of the uneven illuminate is also neglected by the most of the researchers.

4. Visibility Restoration Technique

For removing haze, fog from the image various techniques are used. Typical techniques of image restoration to the haze are:

4.1 Dark Channel Prior

Dark channel prior (Wang, Yan *et al,* 2010) is used for the estimation of atmospheric light in the dehazed image to get the more real result. This method is mostly used for non-sky patches; in one color channel have very low intensity at few pixels. The low intensity in the dark channel is predominant because of three components:

- Colourful items or surfaces
- Shadows(shadows of car, buildings etc)
- Dark items or surfaces(dark tree trunk, stone)

As the outdoor images are usually full of shadows the dark channels of images will be really dark. Due to fog (airlight), a foggy image is brighter than its image without fog. So we can say dark channel of foggy image will have higher intensity in region with higher fog. So, visually the intensity of dark channel is a rough estimation of the thickness of fog. In dark channel prior we use pre and post processing steps for getting good results. In post processing steps we use soft matting or trilateral filtering etc. Let J(x) is input image, I(x) is hazy image, t(x) is the transmission of the medium. The attenuation of image due to haze can be expressed as:

$$\mathrm{I_{att}(x) = J(x)t(x)} \quad (1)$$

The influence of fog is Airlight effect and it is shown as:

$$\mathrm{I_{airlight}\,(x) = \; A(1 - t(x))} \quad (2)$$

Dark channel for an random image J, shown as J dark is defined as:

$$\mathrm{J^{dark}(x) = \frac{min}{y \in \Omega(x)} \left(min\, J^{C}\,(Y) \right)} \quad (3)$$

In this J^c is the color image comprising of RGB components, $\Omega(x)$ depicts a local patch which has its origin at x. The low intensity of dark channels is because of shadows in images, color objects and dark objects in images. After dark channel prior, we need to estimate transmission t(x) for proceeding further with the solution. After estimating the transmission map depth map is generated. Assume Atmospheric light A is also known. Figure (2) illustrates the Haze removal results. Top is input haze images. Middle is restored haze-free images. Bottom is depth maps.

Fig 2 Haze removal results. Top: input haze images. Middle: restored haze-free images. Bottom: depth maps.

4.2 CLAHE

Contrast limited adaptive histogram equalization short form is CLAHE (Xu, Zhiyuan *et al,* 2009). Constrast Limited Adaptive Histogram Equalization (CLAHE) is used for enhancement of low contrast images. This method does not need any predicted weather information for the processing of fogged image. Firstly, the image captured by the camera in foggy condition is converted from RGB (red, green and blue) color space is converted to HSV (hue, saturation and value) color space. The images are converted because the human sense colors similarly as HSV represent colors.

(a) (b)

Fig 3 shows (a) input image (b) output image

Secondly value component is processed by CLAHE without effecting hue and saturation. This technique use histogram equalization to a contextual region. The original histogram is cropped and the cropped pixels are redistributed to each gray-level. In this each pixel value is reduced to maxima of user selectable. Finally, the image processed in HSV color space is converted back to RGB color space. Figure (3) illustrates the Results of the improved image using CLAHE technique

4.3 Bilateral Filtering

Bilateral filtering smooths images and it also preserves edges, with nonlinear combination of nearby image values. Bilateral is non iterative, local, and sim- ple. Gray levels or colors are combined by the bilateral filter based on both their geometric closeness and their photometric similar, and prefers close values to distant values in both domain and range. Bilateral filter smooth edges towards piecewise constant solutions. Bilateral filter does not provide stronger noise reduction. Figure (4) illustrates the processing of foggy image and establishment of it into original image by using bilateral filter.

(a) (b) (c)

Fig 4 (a) Original foggy image (b) Defogged image (c) Bilateral defogged image

4.4 MIX – CLAHE

Hitam *et al*. (2013) presented method to enhance underwater images using a mixture Contrast Limited Adaptive Histogram Equalization. The enhancement method effectively improves the visibility of underwater images and produces the lowest MSE and the highest PSNR values. Thus, it has shown that the mix-CLAHE based method is promising for classifying coral reefs especially when visual cues are visible.

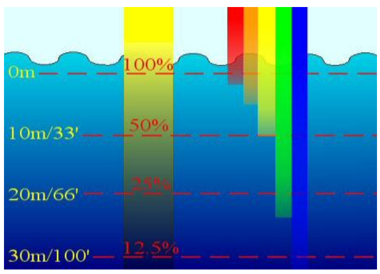

Fig 5 Absorption of light by water

Figure (5) shows an illustration about the absorption of light by water. For every 10m increase in depth the brightness of sunlight will drop by half. Nearly all red light is gone by 50% from the surface but blue continues to great depth. That is why most underwater images are dominated by blue-green coloration. CLAHE-Mix first normalizes the result of CLAHE-RGB. Figure (6) illustrates the results of CLAHE technique operating on RGB and HSV color models and the result of Mix-CLAHE operating on Image. As can be seen from the figure, when CLAHE operated on RGB color model, it corrupts the human sense of color. A more logical approach is to spread the color values uniformly, leaving the colors themselves (e.g., hues) unchanged. The result from CLAHE-HSV shows that the overall color is more sensible than CLAHE-RGB. However, the overall image is much brighter and looks unnatural to image. Moreover, the unavoidable enhancement of noise in smooth regions is identified. To reduce the undesired artifacts as well as brightness in CLAHE RGB and CLAHE HSV images we introduce a new method which mixes the results of CLAHE-RGB and CLAHE-HSV.

The method is called CLAHE-Mix. The aim is to enhance the image contrast and at the same time preserve the natural look of underwater image.

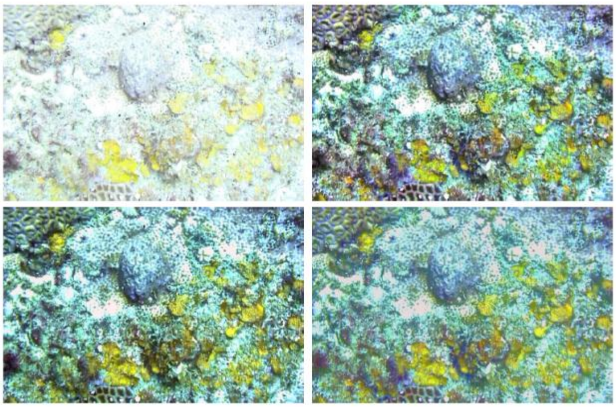

Fig 6 Comparison of CLAHE methods on B1. Upper left: original underwater image. Upper right: CLAHE-RGB image. Bottom left: CLAHE-HSV image. Bottom right: CLAHE-Mix image.

4.5 Trilateral Filtering

This filtering (Cheng, F.C *et al,* 2012)smooth's images without influencing edges, by means of a non-linear combination of nearby image values. In this filter replaces each pixel by weighted averages of its neighbour's pixel. The weight alloted to each neighbour pixel decreases with both the distance in the image plane and the distance on the intensity axis. This filter helps us to get result faster as compare to other. While using trilateral filter we use pre-processing and post processing steps for better results. Histogram stretching is used as post-processing and histogram equalization as a pre processing.

Table 1: Comparison between different image enhancement techniques

S.No	CLAHE	Mix-CLAHE
1.	CLAHE stands for Contrast limited adaptive histogram equalization	Mix-CLAHE stands for Mixture contrast limited adaptive histogram equalization
2.	CLAHE operates separately on RGB and HSV color models	Mix-CLAHE mixes the the results of CLAHE- RGB and CLAHE-HSV color models.
3.	The overall image is much brighter and looks unnatural to underwater image. Moreover, the unavoidable enhancement of noise in smooth regions is identified. This is the result of CLAHE technique operating on RGB and HSV color models.	The result of mix-CLAHE is enhancement of image contrast and at the same time preserves the natural look of underwater image. There is no enhancement of noise in smooth regions is identified.
4.	CLAHE has low Peak signal to noise ratio.	Mix-CLAHE has high Peak signal to noise ratio
5.	CLAHE has high Mean square error.	Mix-CLAHE has low Mean square error.

These both steps help to increase the contrast of image before and after usage of trilateral filter. This algorithm is independent of density of fog so can also be applied to the images taken in dense fog. Table (1) shows Comparison between different image enhancement techniques such as Clahe and Mix-Clahe.

Table 2: Comparison between Filtering Techniques

S.No.	Bilateral Filter	Trilateral filter
1.	Bilateral filtering smooths images while preserving edges, by means of a nonlinear combination of nearby image values	This filtering smooth's images without influencing edges, by means of a non-linear combination of nearby image values.
2.	Bilateral Filtering is non iterative, local and simple	Trilateral filtering requires more iteration in filtering process.
3.	Bilateral filter smooth edges towards piecewise constant solutions.	Trilateral filter smooth edges towards a sharply bounded piecewise linear approximation.
4.	Bilateral filter does not provide stronger noise reduction.	Trilateral filter provides stronger noise reduction

Conclusion

Under water image enhancement based algorithms become more useful for many vision applications. It is found that mostly the existing researchers have neglected many issues; i.e. no technique is precise for various kinds of circumstances. The existing techniques have neglected the use of dark channel prior to reduce the noise and uneven illuminate problem. To overcome the problems of existing research a new integrated algorithm will be proposed in near future. New algorithm will integrate the dark channel prior and mix-CLAHE to improve the results further. The trilateral filtering will be used as a post-processing step to remove the noise from the input image.

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