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A Study on Haze Removal Techniques for Image Processing

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Abstract: This paper presents literature survey on various haze removal techniques. Haze causes problems in various computer vision and image processing based applications as it diminishes the scene's visibility. The air light and attenuation are two main phenomena responsible for haze formation .The air light enhance the whiteness in the scene and contrast get reduced by attenuation. Haze removal techniques helps in recovering the contrast and color of the scene. These techniques have found many applications in the area of image processing such as consumer electronics, object detection, outdoor surveillance etc. The aim of the paper is to explore various methods used for efficiently removing haze from digital images. This paper ends up with the short comings of the existing methods.

Keywords: Airlight, Image Dehazing, Contrast enhancement, Dark channel prior, CLAHE, MIX-CLAHE.

1. INTRODUCTION

Bad weather conditions such as haziness, mist, foggy and smoky degradation in the quality of the outdoor scene. It is an annoying problem to photographers as it changes the colors and reduces the contrast of daily photos, it diminishes the visibility of the scenes and it is a threat to the reliability of many applications like outdoor surveillance, object detection, it also decreases the clarity of the satellite images and underwater images. So removing haze from images is an imperative and broadly demanded area in image processing. The large quantities of these suspended particles in atmosphere cause scattering of light before it reaches the camera which corrupts the outdoor image quality. Haze attenuates the reflected light from the scenes and blends it with additive light in atmosphere. Haze removal techniques tend to improve this reflected light (i.e. scene colors) from mixed light. The constancy and strength of the visual system can also be improved by using this effective haze removal of image. There are many methods available to remove haze from image like polarization independent component analysis, dark channel prior etc.

2. DEHAZING METHODS

Dark channel prior (Wang, Yan et al, 2010)[13] is used to get better result in dehazed image by estimating atmospheric light. This method is considered in cases of non-sky patches with very low intensity at some pixels.
The components responsible for this predominant of low intensity are:

- Colorful items or surfaces
- Dark items
- Shadows

Outdoor images in fog condition are considerably brighter compared to images taken in clear conditions, which results in higher dark channel intensity in dense fog regions.

(a) (b)

Fig 1 (a) Hazy image (b) Dehazed image[1]

In this method, pre and post processing steps are used to get desired outputs.
Assume J(x) is input image, I(x) is hazy image and t(x) is the medium of transmission.
($I_{att}(x)$) is Image attenuation which is caused by haze is represented as:

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

The fog is affected by Airlight , expressed as :

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

$J^{dark}(x)$:Dark channel for the image and is defined as:

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

$J^{c}(Y)$ is the RGB format i.e colored image and Theta x (Ω (x)) depicts a local patch with its origin at x. After this method estimation of transmission t(x) is required before proceeding further. After estimating the transmission map depth map is generated. Assume Atmospheric light A is also known. Fig.2 illustrates the outcomes of method.

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Fig 2: Input images.
Middle: restored dehazed images.
Bottom: depth maps.[5]

2.1. CLAHE

Contrast limited adaptive histogram equalization(CLAHE) (Xu, Zhiyuan et al, 2009)[15]. It is used for contrast enhancement of images. This method doesn't require any weather information before the process of fogged image.1) Convert input image from RGB format to HSV color space. This image conversion is required as human sense colors in same way as colors are represented in HSV format.2) CLAHE is used to process the value component without affecting hue and saturation of image. [15] The method uses histogram equalization to a contextual region. Each pixel of original image is in the center of the contextual region. The original histogram is clipped and the clipped pixels are redistributed to each gray level. The new histogram is different from the original histogram, because each pixel intensity is limited to a user-defined maximum.

In last step, the input image processed in HSV format is converted back in RGB format. Fig.3 illustrates the result of dehazed image using CLAHE method.

Fig3(a)input image (b)output image

2.3. Bilateral Filtering

Bilateral filter smooth the image along with preserving its edges. It is simple and non iterative. By the bilateral filter, gray levels are combined based on properties such as the photometric similarity and geometric closeness, the preference is made based on the values closer compared to distant values in both range and domain.

(a) (b) (c)

Fig 4 (a) Input image (b) Defogged image (c) Bilateral defogged image [5]

The filter is used to smooth edges towards piecewise constant solutions. Bilateral filter does not provide stronger noise reduction.

2.2 MIX – CLAHE

Hitam et al. (2013)[10] proposed a method which can be used to improve underwater image details, it is based on CLAHE. The visibility of the underground image is improved by this method. It produces the maximum PSNR and the minimum MSE values. Thus, this method is able to classify the coral reefs.

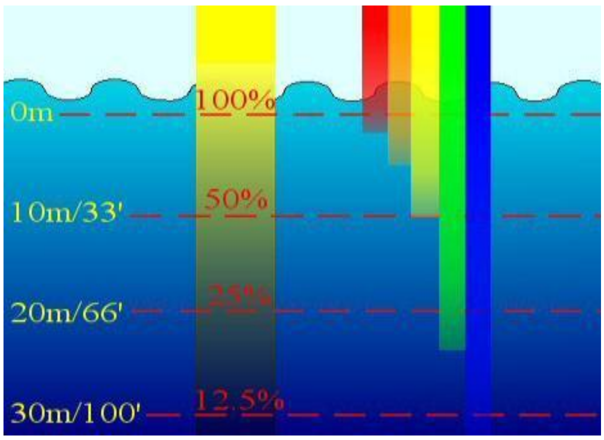

Fig 5 Light Absorbed by water

Figure (5) absorption of light by water is illustrated in this image. By 10 meter increase in depth the brightness of sunlight will decrease to half. All blue light continues to

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greater depth whereas all red is reduced by 50% from the surface. This is because the most underwater images are conquered by green-blue coloration. CLAHE-RGB is result of first normalizing applied on CLAHE-MIX. Figure (6) shows the results of Mix-CLACHE working on image and CLACHE techniques result applied on HSV and RGB color models. As the figure illustrates the it gives the human sense of color when applied RGB color model. A much better and logical approach can be the spread of color values uniformly, leaving the colors themselves (e.g., hues) unchanged. The CLAHE-HSV result shows that the overall color is more rational in comparison to CLAHE-RGB. But, the overall image looks unnatural and is much brighter. Also, there is enhancement of noise in smooth regions is identified which is unavoidable. In order to reduce the the brightness and unwanted artifacts in CLAHE HSV and CLAHE RGB images. New approach was introduced which is the output of mix result of both HSV and RGB images.

This method of mixing both images is known as CLACHE-MIX. The method aimed to enhance the contrast of the image while preserving the natural look of underwater image.

2.4 Trilateral Filtering
This filter (Cheng, F.C et al, 2012) [14] smooth images, by using a non-linear combination of neighbor pixel values with no effect on edges. In this method average weighted values replaces the each pixel value of its neighborhood pixels. The allotted weighted value of each neighbor pixel will decreases as the distance in the image plane and distance on the intensity axis increases. The filter is faster in comparison with other methods. For pre-processing it uses the histogram stretching and equalization of histogram for post-processing.
Histogram stretching and equalization are required to effectively increase the contrast of image. The algorithm used here is independent of fog's density so it can be used for the images taken in dense fog weather conditions.

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	It operates separately on HSV and RGB color space	It combines the results of RGB and HSV color models.
3	The output image looks much brighter and Unnatural. Also, the noise enhancement is identified in smooth region is unavoidable.	The mix-CLAHE enhances the contrast of image and also preserves the natural look of underwater images. No noise enhancement is identified in smooth regions
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.

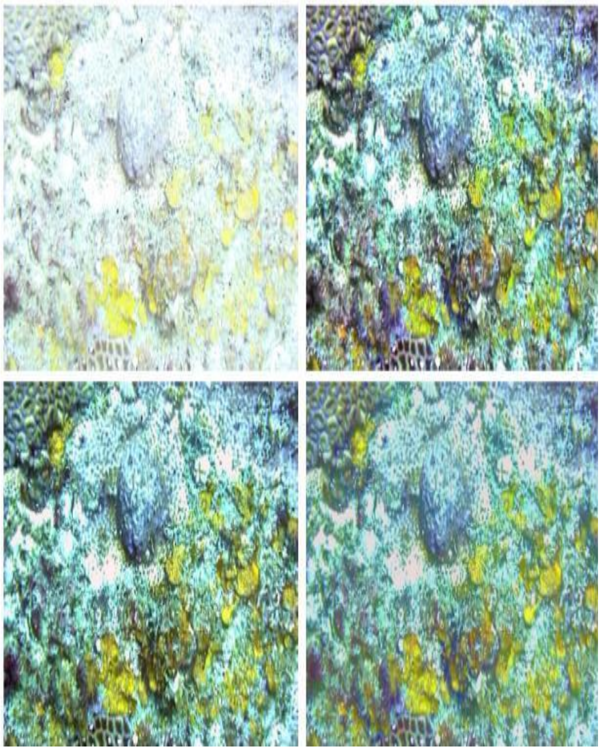

Fig 6 Comparison between different methods. First image is the: original underwater image. Second image shows CLAHE-RGB image. Third output show CLAHE-HSV image and CLAHE-Mix result is shown is last image.

3. LITERATURE SURVEY

Robby T. Tan (2008) [1] has introduced adaptive method which only needs a single input image. Two observations are made based on this method, first, higher contrast in images taken on clear day compared to images clicked in bad weather; and second is the airlight which mostly varies with the distance between objects and the observer. On the basis of these observations Tan[1] developed a framework of Markov random fields with a specific cost function. The results have larger saturation values and may contain halos at depth discontinuities.

Tarel et al. (2009) [2] have demonstrated algorithm for visibility restoration from a single image using a filter method. The algorithm is based on linear operations and needs various parameters for adjustment. It is advantageous in terms of speed which allows visibility restoration process applicable for real-time operations. They also proposed a new filter which preserves edges and corner as an alternate to the median filter. The restored

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image may not be good because of scene depth discontinuities .

Yu et al. (2010) [3] have proposed atmospheric scattering model based new fast dehazing technique. The model is simplified earlier to visibility restoration. First they acquire a coarse approximation of the atmospheric mask and then the coarser estimation is smoothed using bilateral filtering process which also preserve the edges. The only complexity with the method is the number of linear function in input image pixels which is the reason behind fast computation.

Fang et al. (2011) [4] have discussed atmospheric scattering model based fast haze removal algorithm from multiple images in similar weather conditions. The basic idea is to create a determined system which compares the hazy images to the images taken in clear weather through which transmission and global airlight can be acquired. The transmission and global airlight obtained from the equations can be applied to the local hazy area. The discussed algorithm reduces haze effectively and achieves accurate restoration.

He et al. (2011) [5] proposed a dark channel prior based method to effectively remove haze from single input image. The dark channel prior is a type of statistics of outdoor haze-free images. In cases of the non-sky patches, haze transmission can be estimated by the dark or very low intensity pixels. They can directly evaluate the thickness of the haze using this model and can get dehazed output image. The dark channel prior does not work efficiently in the cases when the object can't be differentiated from the atmospheric light.

Long et al. (2012) [6] proposed a method for dark channel prior which is physical- based fast method and can easily extract the atmospheric light. Also roughly calculate the atmospheric veil with the dark channel of given haze image. Then using Low-pass Gaussian filter it refine the atmospheric veil. In maximum cases, good/ accurate outputs are obtained. The results have color distortion when input images heterogeneous and dense haze especially in the loss of details cases and bright regions.

Zhang et al. (2012) [7] have described a new algorithm that is based on an image filtering process consist of the median filter and uses low-rank technique for the enhancement of visibility. The atmospheric veil is estimated with Monte Carlo simulation. The shortened single value decomposition and the dark channel prior are used to obtain dehazed image. This method may not perform well in the scenes with great depth and heavy fog. It also suffers from halo effects.

Xu et al. (2012) [8] proposed an improved dark channel prior by replacing the time consuming soft-matting part with the fast bilateral filter. This algorithm has a greater efficiency, fast execution speed and improves the original algorithm. Also, the reasons why the dark channel prior leads to dim image after the haze removal, and proposed the improved transmission map formula in order to get the improved visual effects of the image. Traditional algorithm is not suitable for the sky region, so they used weaker method to enhance the flexibility of the improved algorithm.

Ullah et al. (2013) [9] proposed a single image dehazing method using improved dark channel prior. The dark channel prior has been further polished. Both achromatic (neutral) and chromatic features of the image are considered by proposed model to describe the Dark Channel. Improved Dark channel take minimum of saturation (1-S) and intensity (I) components instead of RGB components. Refined Dark Channel increases value of restored haze free images. It maintains color reliability and improves the contrast. Somehow it decreases the pixel color saturation.

Hitam et al. (2013) [10] proposed a new method called mixture Contrast Limited Adaptive Histogram Equalization (mix-CLAHE) model which is specifically developed for enhancement of underwater images. The method operates separately on HSV and RGB format of image and then the results of both are combined together by mean of Euclidean norm. The central objective of the method is to reduce extensive noise introduced after CLAHE to ease the processing of underwater images with high efficiency. This method can be used to improve the visibility of underwater images.

Abdul Ghani et al. (2015)[11] proposed a Rayleigh distribution based technique which successfully improved the contrast, increase the details, reduce the blue-green effect and noise of underwater images, and also minimizes under- and over- enhanced areas in output image. But the problems of uneven illuminate is neglected.

Wang et al. (2015)[12] proposed a physical model and dark channel prior principle based a single image dehazing method and also a fast transmission estimation algorithm which can shorten the processing time and also improve the operational efficiency. Image quality was evaluated on the basis of three indicators MSE, PSNR, average gradient along with subjective evaluation. But noise reduction techniques were neglected.

4. GAPS IN LITERATURE

Dehazing algorithms has been essential part for various computer vision and image processing based applications. But most of the existing methods have several research gaps such as:-

- Noise reduction techniques are neglected.
- No approach toward integration of CLAHE and Dark Channel Prior algorithm.
- The uneven illumination problem has been neglected, which degrade the results of dehazing algorithms in existing research.
- Not much effort is done in the field of remote sensing and underwater images.

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5.CONCLUSION

Haze removal algorithms have become a need for various computer vision based applications. But in already existing approaches, many aspects have been neglected i.e. No technique is accurate in different situation. Survey has displayed the neglected points in the presented methods like the noise reduction methods. The problem of uneven and over illumination is also an issue for dehazing methods. So there is a need of modification in the existing methods so that existing methods work in better way. An integrated dark channel prior, CLAHE and bilateral filter combined algorithm can be used to get better results.

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