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A Review on Various Visibility Restoration Techniques

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Abstract: Fog removal also known as visibility restoration refers to different methods that aim to reduce or remove the degradation that have occurred while the digital image was being obtained. The degradation may be due to various factors like relative object-camera motion, blur due to camera miss-focus, relative atmospheric turbulence and others. This paper has focused on the various fog removal techniques. Haze removal has found to be tough task because fog depends on the unknown scene depth information. Fog effect is the function of distance between camera and object. Therefore, the removal of fog requires the estimation of air light map. The current haze removal technique can be categorized as: image enhancement and image restoration however, the image enhancement does not incorporate the reasons of fog corrupting the image quality.

Index terms: Fog removal, image enhancement, visibility restoration

I. INTRODUCTION

Visibility restoration [1] refers to different methods that aim to reduce or remove the degradation that have occurred while the digital image was being obtained. The degradation may be due to various factors like relative object-camera motion, blur due to camera misfocus, relative atmospheric turbulence and others. In this we will be discussing about the degradations due to bad weather such as fog, haze, rain and snow in an image. The image quality of outdoor screen in the fog and haze weather condition is usually degraded by the scattering of a light before reaching the camera due to these large quantities of suspended particles (e.g. fog, haze, smoke, impurities) in the atmosphere. This phenomenon affects the normal work of automatic monitoring system, outdoor recognition system and intelligent transportation system. Scattering is caused by two fundamental phenomena such as attenuation and airlight. By the usage of effective haze removal of image we can improve the stability and robustness of the visual system.

Fig 1.1: (a) Original image (b) Processed image (adapted from [1])

Haze removal is a tough task because fog depends on the unknown scene depth information. Fog effect is the function 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: image enhancement and image restoration. Image enhancement does not include the reasons of fog degrading image quality. This method can improve the contrast of haze image but loses some of the information regarding image. Image restoration firstly studies the physical process of image imaging in foggy weather. After observing that degradation model of fog image will be established. At last, the degradation process is inverted to generate the fog free image without the degradation. So, the quality of degraded image could be improved.

II. VISIBILITY RESTORATION TECHNIQUE

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

A. Dark channel prior: Dark channel prior [2] is used for the estimation of atmospheric light in the dehazed image to get the more proper result. This technique is mostly used for non-sky patches, as at least one color channel has very low intensity at some pixels. The low intensity in the dark channel are predominantly because of 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)

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

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

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

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

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

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

In this Jc is color image comprising of RGB components, represents a local patch which has its origin at x. The low 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 need to estimate transmission t(x) for proceeding further with the solution. Another assumption needed is that let Atmospheric light A is also known. We normalize (4) by dividing both sides by A:

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

Figure 1: Haze removal results. Top: input haze images. Middle: restored haze-free images. Bottom: depth maps.

B. CLAHE

Contrast limited adaptive histogram equalization short form is CLAHE [3]. This method does not need any predicted weather information for the processing of hazed image. Firstly, the image captured by the camera in foggy condition is converted from RGB (red, green and blue) color space is converted 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 effecting hue and saturation. This method use histogram equalization to a contextual region. The original 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.

Figure 2: (a) input image

Figure 2: (b) output image

C. Wiener filtering

Wiener filtering [4] is used to counter the problems such as color distortion while using dark channel prior when the images with large white area is processed. While using dark channel prior the value of media function is rough which create halo effect in final image. So, median filtering is used to estimate the media function, so that edges can be preserved. After making the median function more accurate it is combined with wiener filtering so that the image restoration problem is transformed into optimization problem. This algorithm is useful to recover the contrast of a large white area for image. The running time of image algorithm is also less.

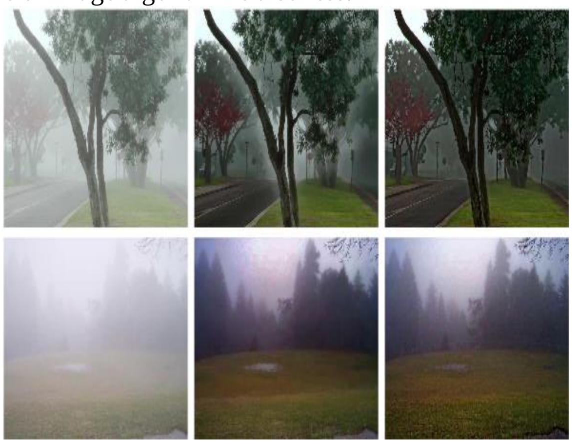

Figure 3: (a) Original foggy image (b) Defogged image (c) Weiner defogged image

D. Bilateral filtering

This filtering [5] smooth's images without effecting 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 assigned 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 bilateral filter we use pre-processing and post processing steps for better results. Histogram equalization is used as pre-processing and histogram stretching as a post processing. These both steps help to increase the contrast of image before and after usage of bilateral filter. This algorithm is independent of density of fog so can also be applied to the images taken in dense fog. It does not require user intervention. It has a wide application in tracking and navigation, consumer electronics and entertainment industries.

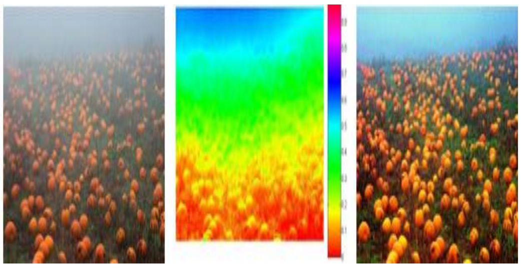

Figure 4: (a) original foggy 'pumpkins' image, (b) corresponding air light map using bilateral filter, and (c) Restored image

III. LITERATURE SURVEY

Tae Ho Kil et al. (2013) [6] has proposed the dehazing procedure constructed on dark channel prior and contrast enrichment methods. The orthodox dark channel prior scheme eradicates the haze and thus restores the colors of the objects in the view, but it does not take into account the improvement of image contrast. On the other hand, the image contrast technique increases the local contrast of objects, however the colors are frequently distorted due to the over-stretching of contrast. The projected procedure combines the benefits of the both conventional methods for the possession the color. Aimed at this situation, an optimization function is introduced to keep a balance among the contrast and colors distortion. The proposed methodology adjusts for the drawbacks of conventional methods, and improves the contrast with reduce color alteration.

E. Ullah et al. (2013) [7] evaluated that environmental conditions such as haze, fog or rain noticeably affects the visibility. The water droplets existing in the atmosphere produce mist, fog and haze results due to dispersion of light as it circulates through these particles. These chromatic effects of image dispersion can be reversed for recovery of image knowledge. A single image dehazing technique using dark channel prior has been broaden. The suggested model considers both chromatic and achromatic features of the image to define the Dark Channel. Foremost application regions of real time single image dehazing involve tracking system, consumer electronics and entertainment industry.

Muhammad Suzuri Hitam et.al. (2013) [8] has evaluated a new method called mixture Contrast Limited Adaptive Histogram Equalization (CLAHE) color models that exactly established for underwater image improvement. The technique works CLAHE on RGB and HSV color models and the results are joint together using Euclidean norm. The images considered in this study were taken from Redang Island and Bidong Island in Terengganu, Malaysia. Enhancing the property of an underwater image has received significant attention due to poor visibility of the image which is caused by physical properties of the water medium. The proposed method significantly improves the visual quality of underwater images by enhancing contrast, as well as reducing noise and artifacts. Abhishek Kumar Tripathi et al. (2012) [5] has examined a novel and effective fog removal algorithm. The algorithm practices bilateral filter for the approximation of air-light. By way of the given process is free from the concentration of fog and don't entail user interference. It can tackle both color as well as gray images. Haze creation is due to attenuation and airlight. Attenuation decreases the contrast and airlight upsurges the paleness in the scene. The procedure has an extensive application in tracking and direction-finding, customer electronics and entertainment. It was observed that, in foggy image estimated air light map depends upon the distance of scene points from camera. Estimated air light map is able to capture the discontinuities across the edges and smooth over the objects.

F-C. Cheng et al. (2012) [10] has discussed that the lowest level channel prior for effective image fog removal. The use of the lowest level channel is simplified from the dark channel prior. It is based on a key observation that fog-free intensity in a color image is usually the minimum value of trichromatic channels. To estimate the transmission model, the dark channel prior then performed as a min filter for the lowest intensity. The the transmission model is recalled to defog an image; then accelerated the refinement of transmission by initiating a fast O (1) bilateral filter based on the raised cosines function to the weight values of neighbors. As compared to the soft matting approach, the suggested strategy results in considerable savings in the cost of transmission refinement.

A.K. Tripathi and S. Mukhopadhyay (2012) [11] have proposed a novel and efficient fog removal algorithm. The fog formation is because of the attenuation and the air-light i.e. the attenuation reduces the contrast and air-light increases the whiteness in the scene. Single image fog removal using anisotropic diffusion uses an anisotropic diffusion to recover a scene contrast. Simulation consequences prove that the algorithm outperforms prior state-of-the-art algorithms in terms of contrast gain, percentage of number of saturated pixels and computation time. The given algorithm is independent of the density of fog and does not require user intervention. It can handle color as well as grey images. Along with the RGB color model, this algorithm can work for HSI model that further reduces the computation.

Yanjuan Shuai et al. (2012) [4] has studied that, with the use of the image haze removal of dark channel prior, one is prone to color distortion phenomenon for some wide white bright part in the image. An image haze removal of wiener filtering based on dark channel prior has been proposed. The given algorithm based on dark channel prior is mainly to evaluate the median function in the usage of the media filtering technique based on the dark channel, as to make the media function more precise and combine. The foggy image reestablishment problem is altered into an optimization problem, and by minimizing the mean-square error a clearer, a fogless image is finally obtained. The proposed algorithm can recapture the contrast of a big white area of foggy image and compensates for the lack of dark channel prior algorithm.

Haoran Xuet et al. (2012) [2] after a profound study on the haze removal technique of single picture over quite a while has actualized a quick haze evacuation algorithm, in light of fast bilateral filtering aggregated with dark colors prior. The calculation begins with the barometric scattering model, infers an expected transmission map utilizing dark channel prior, and afterward consolidates with gray scale to extract the refined transmission map with the help of fast bilateral filter. It has a quick execution rate and extraordinarily enhances the original algorithm, which is more prolonged. On this groundwork, it has been demonstrated that the why the picture is lower after the haze evacuation utilizing dark channel prior. So another calculation is proposed which has enhanced transmission map recipe. The picture with extensive region of sky typically inclined to distortion when utilizing the dark channel prior, hence a technique of weakening the sky region, intends to enhance the flexibility of the calculation was proposed.

Jiao Long et al. (2012) [14] has introduced a basic however successful technique to uproot haze or fog from a solitary remote sensing picture. This technique is depends upon the dark channel prior and a normal cloudiness-imaging model. Remote sensing pictures are broadly utilized within different fields. In any case, they generally experience the ill effects of the awful climate conditions, which likewise influence their sufficient utilization. A low-pass Gaussian channel is used to refine the coarse evaluated atmospheric veil. However this methodology attains great effects with almost no transforming time.

Kaiming He et al. (2011) [15] has concluded that the dark channel prior is a sort of statistics of outdoor haze-free images. It is dependent upon a key perception that the most nearby patches in outdoor haze-free images encompass some pixels whose strength is very low in at least one color channel. Utilizing this with the cloudiness imaging model, one can specifically assess the thickness of the fog and recover an amazing haze free picture. Additionally, a high quality map can likewise be gotten as a side effect of cloudiness evacuation. Therefore, these dark pixels can straight forwardly give a precise estimation of the fog transmission. Joining a haze imaging model and a delicate matting interpolation system, an excellent fog free picture can be recovered.

IV. GAPS IN LITERATURE

Fog removal algorithms become more beneficial for numerous vision applications. It has been originated that the most of the existing research have mistreated numerous subjects. Following are the various 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 CLAHE and Dark channel prior.
(3) The problem of the uneven illuminate is also neglected by the most of the researchers.

V. CONCLUSION AND FUTURE WORK

Fog removal algorithms have become more useful for many vision applications. It is found that most of the existing researchers have neglected many issues; i.e. no technique is accurate for different kind of circumstances. The existing methods have neglected the use of histogram stretching and Gabor filter to reduce the noise problem which will be presented in the output image of the existing fog removal algorithms. 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, CLAHE and histogram stretching to improve the results further. The Gabor filtering is also done as a pre-processing step to remove the nosie form the input image.

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