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A Review on Fog Removal Techniques

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Abstract — *Fog, haze and smoke are a big reason of road accidents. Fog reduces contrast level of the image that affects the visual quality of the image. In field of computer vision visual quality and visibility level of an image is affected by airlight and attenuation phenomena. Air particles, which present in atmosphere and affect the visibility level of any object, are called noise or unwanted signal between observer and object. For improving the visibility level of an image and reducing fog and noise various image enhancement methods are used. After enhancement is again restored the enhanced image by restoration methods. For improving the visibility level 4 major steps are used. First step is acquisition process of foggy images. Second is estimation process (estimate scattering phenomena, visibility level). Third is enhancement process (improve visibility level, reduce fog or noise level). Last step is restoration process (restore enhanced image). The main aim of this paper is to review state-of-art image enhancement and restoration methods for improving the quality and visibility level of an image which provide clear image in bad weather condition. We also compare prevalent approaches in this area through implementation of the methods keeping parameters common for critical analysis. In the end we provide the future scope for working directions in this area for the readers.*

Keywords*- Fog Removal, restoration, image acquisition, air light, attenuation, visibility enhancement, contrast enhancement*

I. INTRODUCTION

Fog is a collection of water droplets or ice crystals draped in the air at or near the earth surface. Fog in form of cloud is known as stratus cloud. Fog is prominent from mist only by its density. Fog reduces visibility to less than 1 km whereas mist reduces visibility to no less than 1 km.

1.1 Type of fog

Radiation fog, Ground fog, Advection fog, Evaporation fog, Arctic sea smoke, Precipitation fog, Upslope fog, Freezing fog, Frozen fog, Artificial fog are some of most recurring fog type.

Table 1. Visibility and weather Condition of Fog, Mist, Haze

	VISIBILITY	WEATHER CONDITION
FOG	Visibility less than 1 km	Cloudy
MIST	Visibility between 1 & 2 km	Moist
HAZE	Visibility between 2 & 5 km	Dry

1.2 Effect of Fog

Effect of fog mainly is caused by two scattering [1, 2] phenomenon-

Attenuation - The light beam coming from a scene point gets attenuated because of scattering by atmospheric particles, called attenuation that decreases the contrast of the scene. Fog particles add into 3D GIS (Geographic information system) [3].

Airlight - The light coming from a source is scattered toward camera and give on to the shift in color, it's called airlight. The fog effect is the function of the distance between scene point and viewer or camera. Hence, removal of fog requires the estimation of airlight map [4, 5].

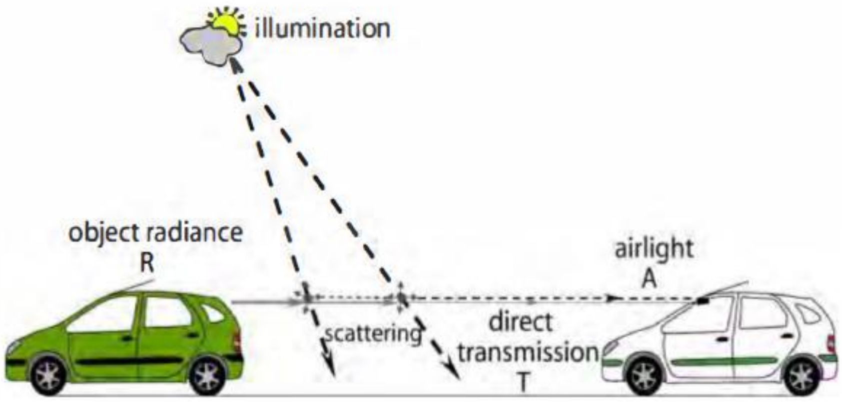

Figure 1. Scattering phenomena Airlight and Attenuation

The depth information of any input image is measured in term of airlight [6], transmission map [I], depth map or some time depth information is estimated with the use of scene properties. Initial work in fog removal is based on the contrast enhancement and restoration based approaches.

Under fog, haze and smoke weather conditions, the contrast and color characters of the images are degraded in a drastic manner. On Clear day images have high contrast compare than foggy images. Thus, a fog removal algorithm should improve the scene contrast [7].

Fog reduces visibility and contrast level of an image. To improve the quality of images various enhancement methods are used. A step by step image processing is applied over an image. Firstly acquire the image from real world and convert into system readable form, measurement of the effect of noise on the image. There are different types of noise which affects the image. Accordingly, image enhancement process for improving the quality of an image is needed then. After improving the quality of an image again restore that image. At present technology for fog removal are of two types -

i. Fog Correction

ii. Fog Removal

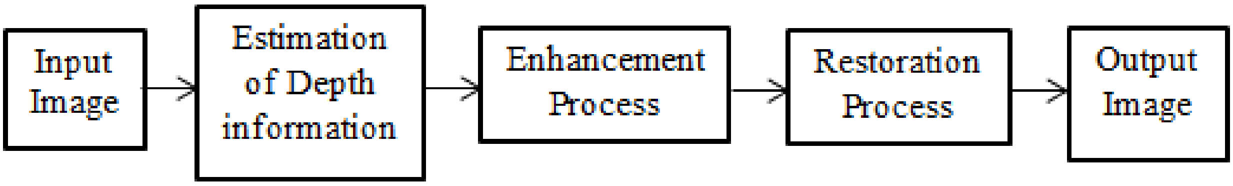

Figure 2. Framework for fog removal

The Fog correction is based on correction of contrast level. Color correction process is applied over HSV color space [1]. Color correction process generates transmission map and estimates atmospheric light resulting a defogging image. Further using color correction method enhanced video is created. Fog correction process improves the quality of foggy pixel but in fog removal process the fog level over an image is found out and removed.

II. IMPROVED SINGLE IMAGE DEHAZING ALGORITHM

For removing haze, fog, mist from the image various technique are used. Typical methods of improved single image dehazing algorithm to the fog are:

2.1 Dark channel prior

Dark channel prior [8] 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 is 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:

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

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

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

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

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

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:

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

Figure 3. Haze removal results. Top: input haze images, Middle: restored haze-free images, Bottom: depth maps

2.2 CLAHE

Contrast limited adaptive histogram equalization short form is CLAHE [9]. This method does not need any predicted weather information for the processing of hazed image.

Figure 4. Input Image

Figure 5. Output 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.

2.3 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 6. (a) Original foggy image (b) Defogged image (c) Weiner defogged image

III. LITERATURE SURVEY

Tae Ho Kil et al. (2013) [11] 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) [12] 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 broadening. 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) [13] 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. 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.

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 airlight 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) [10] 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) [8] 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.

Kaiming He et al. (2011) [4] 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. CONCLUSIONS

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 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.

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