© July 2022 | IJIRT | Volume 9 Issue 2 | ISSN: 2349-6002

Fog Density Estimation and Elimination of Fog in Single Image

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***Abstract*— In the present work, we empirically study the problem in the important task of image fog and remove the fog from a picture using an image defogging algorithm. Dirt, fumes, and other fragments distort the perception of the sky, reducing clarity. Foggy pictures generate a variety of vision issues for drivers and visitors everywhere, particularly in mountainous places where there is a lot of Haze and fog. So, a fog removal algorithm can reduce these types of impacts. Outdoor photographs were utilized with certain filters be concerned to locate the mist in the image. In RGB (Red, Blue, Green) channels, any one of the color channels has a modest value in hazy/ foggy photos. The air-light depth map is primarily responsible for the intensity of these pixels. Obtaining a good quality dehazed image requires approximating these low-value spots on the mist transmission map. To get a high-standard defogged image, a training model is used. The method has been tested on datasets that contain outdoor photos. This method also enhances the visibility of an image.**

Index Terms—Defogging, Single Image, Image enhancement, trained model, PSNR.

I. INTRODUCTION

Because of the reflection of sunlight from air pollution, water globules in the atmosphere, or a mix of both fog and smoke, outdoor images lose quality. Mist is a natural phenomenon that occurs when dirt and smoke molecules mix together to reflect sunlight, causing insight impairment. Because of the interference, the camera's vision has deteriorated with the dust particles reflecting the ambient light source. The noise in the blurred pictures increases, while the color attenuation decreases as shown in fig 1. In domains as diverse as digital processing, computer vision algorithms, and photography, haze reduction is extremely desirable. The clarity of hazy images generated by air particles improves when haze is removed from the image. From larger scale image processing to advanced scale form identification, most computer image processing approaches assume that the associated picture is the scene Luminant.

Fig1. Foggy Image which is blurred

The effectiveness of these strategies is determined by the circumstances. If the visual or scenario is uninteresting, vision algorithms will have a lot of problems and will not work well. As a result, eliminating haze is necessary for improved outcomes and efficiency. The photographs that aren't so good can be put to greater use. The degree of dispersion is related to the camera's distance from the scene, and this deterioration is spatially variable. The clarity of hazy images generated by air particles improves when haze is removed from the image. Pictures without haze are more appealing than images with haze. The upcoming sections are the breakdown of the paper's format. The relevant literature on picture dehazing is included in part II. The methods used to solve the problems are shown in part III. The outcomes of the experiments and their analysis are provided in part IV. The research work comes to a close in the last segment.

II. BACKGROUND

Many Techniques have been proposed so far today for haze and fog removal using the various method for single and multiple images. Fusion-based wavelet method kind of removing blurriness in bad weather conditions [2], methods like polarization-based with a various degree [3], Physics methods based and also depth statistics from the 3D models which remove the fog from the picture are proposed. Images acquired under foggy settings suffer from contrast attenuation and color distortion due to air particle dispersion as shown in fig2, which has a significant impact on the effectiveness of machine vision systems. To increase visual clarity, a variety of technologies have been devised.

Image enhancement and haze removal are difficult tasks in computer vision. The standard image dehazing model is as following equation

$$I_O(x) = I_{ATTENUATION}(x) + I_{AIR-LIGHT}(x) \quad (1)$$

The attenuation and air-light equations can be as shown in the equation 2 and 3

$$I_{ATTENUATION}(x) = J_O(x)t_O(x) \quad (2)$$

$$I_{AIR-LIGHT}(x) = A\left(1 - t_O(x)\right) \quad (3)$$

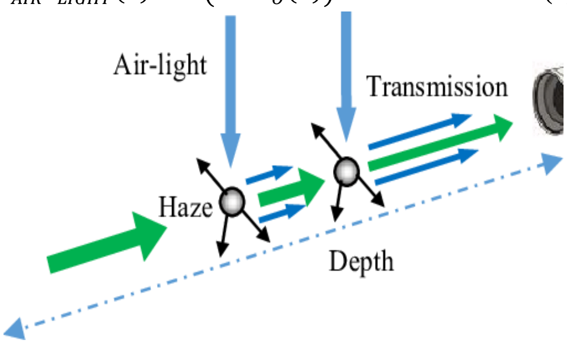

Fig2. Atmosphere Scattering model

Where in equation 1 I_O represents the observer intensity, In the equation(2) J_O represents scene image radiance, A in equation (3) is the light of atmosphere & t_O represents the transmission medium that shows the sun light which does not scattered and that comes out the camera. The primary motive of any defogging algorithm is to regain the picture scene radiance from the input foggy picture that can be expressed in the equation as show in (6).The transmission medium when the climate is homogeneous is expressed as

$$t_o(x) = e^{-D_o(x)} \quad (4)$$

Where

$$D_o(x) = \beta do(x) \quad (5)$$

β and do represents the scattering coefficient and image scene depth respectively.

In [1] tan discovers that a haze-less picture has more contrast, thus he covers the mist image by enhancing the recovered image's local contrast. The procedure, somehow, is physically not valid presuming that surface shading isn't locally connected to transmission,[4] He et al. proposed effective and simple algorithm called as DCP (dark channel prior method) which generally shows a good result on the outdoor pictures by examining the features of a large number of foggy outdoor photographs where If the image is broken into numerous local patches and there would be one of the color channels strongest values is relatively low .The dark channel can be expressed as

$$J_0{}^{dark}(x) = {}_{y\in\Omega(x)}^{min}(min J_O^c(y)) \quad (6)$$

Where in equation c represents the RGB channel, for any fog free picture dark channel has very less intensity or it tends to zero.

$$J_0{}^{dark} \;--\!\to 0 \quad (7)$$

With respect to the dark channel equation transmission by keeping a small fog for distant scene

$$\tilde{t_0}\ (x) = {}_{y\in\Omega(x)}^{1} - \omega \min\left(min \frac{Io^c(y)}{Ao^c}\right) \quad (8)$$

Equation 9 shows that the objective of any defogging algorithm is to regain the fog less picture from the input foggy images.

$$J_O = \frac{I_O - A_O(1-t_O)}{t_O} \quad (9)$$

III. PROPOSED SYSTEM

In the proposed system Image is enhanced based on the study of fog related features from the foggy pictures which corelate well the depth is studied and based on the learned model the feature is compare with the model and defogging is done. The image defogging approach of the proposed system is given in the figure 3.

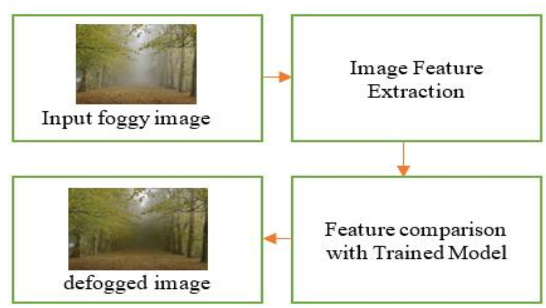

Fig 3. Image defogging system process.

The definition of hazy is that is clouded or covered by mist or something unclear, vague or not well defined. The images that are captured in this climate are called as foggy images and these images are not properly visible and are the input to the model. Fog is one of the important factors that can minimize the quality of a picture so varying components such as luminance, color, and contrast is because of the fog present in outside pictures. The informative relevant features can be studied and selected which will predict using traits found in a big number of photos, forecast the quality of distorted photographs.

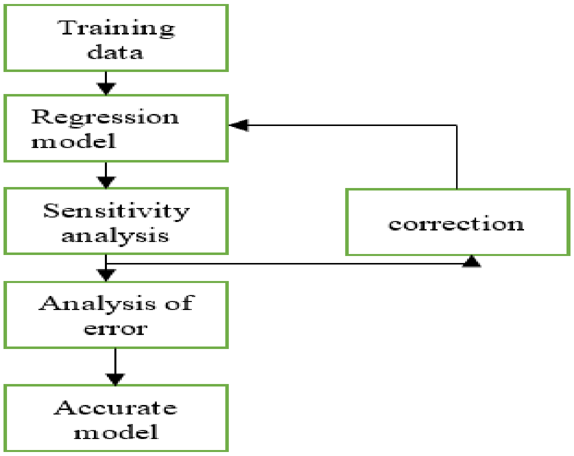

Fig 4: model for the proposed system

Once the fog density is obtained the image is defogged and enhanced image is obtained. Based on the studied fog related features regression model for estimating the depth of the picture is used. The flowchart of the surrogate modelling is as shown in the fig4.Tang et[1] developed a method for creating foggy photos from fog-free photographs. The depth maps are created for each of the fog-less images with different fog densities. The construction of the model can be aims to find a function from limited number of data. For the model construction there are two approaches parametric and non-parametric. The second order model for estimating the optical depth is given[5] by the equation(10).

$\hat{D}(x) = B_0 + \sum_{p=1}^{7} B_p\, f_p^1(x) + \sum_{p=1}^{7} \sum_{j>=1}^{7} B_{pj}\, f_p^1(x) \quad f_j^1(x)$ (10). The prediction accuracy of PRG models can be done using statistical methods such as modified coefficient of multiple determinations and root mean square error $RMSE_a$. The root mean square error $RMSE_a$ is given by [5]

$$RMSE_a = \sqrt{\sum_{i=1}^{n} \varepsilon_i^2 / n - n_p} \qquad (11)$$

Where ε_i represents the error between from observed scene & the calculated output value.

The steps of the proposed system is as shown in the fig5. The fig 5 shows the steps in the proposed system for obtaining the fog-free image.

A. Input image- The input image is the foggy image which is represented as $I_O(x)$. The images which are captured in the uncleared environment or captured in the foggy conditions are called Foggy image. These foggy images are provided as the input for our system.

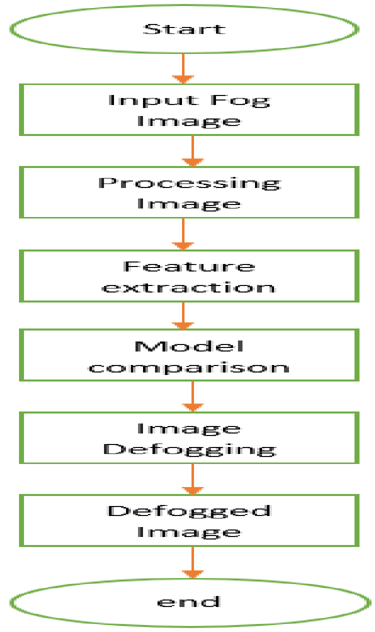

Fig5.Image defogging steps in the proposed system

$$I_O(x) = J_O(x)t_O(x) + A(1 - t_O(x)) \qquad (12)$$

B. Processing Image: Once the image is captured then it has to be processed and it involves the steps such as grayscale image , image thresholding, and binarization.

C. Edge based detection and Feature extraction: Edge detection is a technique used in computer vision to locate the borders of an image in a photograph in digital image processing.

This method employs a search algorithm that looks for pixel brightness discontinuities in a grayscale picture. Using segmentation and extraction algorithm approaches, software can find features, objects, and even landmarks in an image.

D. Feature comparison with model: Once the feature is extracted then it is compared with already learned model which helps to identify the foggy elements and reduce the foggy appearance in the image.

E. Output Image: This is the required defogged image which is to be obtained which is given by the equation (13)

$$J_O(x) = \frac{I_O(x) - A_O(1 - t_O(x))}{t_O(x)} \qquad (13)$$

IV. EXPERIMENT RESULTS AND DISCUSSION

The framework has built up a programmed defogging framework utilizing characteristic image defogging model system for example, the image which has taken in the foggy conditions are enhanced to fog-less pictures. Following snapshots shows the result of proposed work:

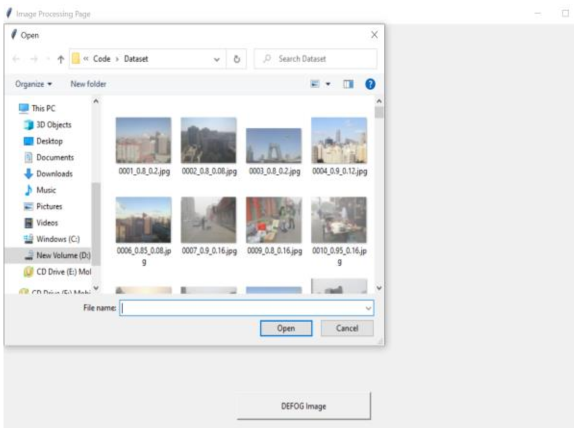

Fig6: Giving Image path to obtain foggy-free image

Fig 7 is the defogged image output of our proposed system and Table 1 represents the Peak signal to noise ratio value of the proposed system. Peak signal-to-noise ratio (PSNR) [11] is a measure of how well a picture may be represented by a signal compared to the amount of noise that can damage it.

The ratio is used as a quality measurement between the original input image and a output defogged image. The better the quality of the reconstructed image is known by this calculation.

PSNR Can be calculated as shown in the equation

$$PSNR = 20log_{10}(\frac{(L-1)}{RMSE}) \qquad (14)$$

Where in equation 14 RMSE is the root mean square error which is obtained by equation 11, and L is the maximum possible intensity levels. The framework is tested for both outdoor and indoor real world images and synthetic images as shown in fig 7. The Framework tested results for synthetic images(Input Image 1 and 3), Indoor real world images(Input image 2 and 3),Outdoor Images(Input Image 4,5,6,8) respectively. Table 1 represents the PSNR value of our result image. The execution time for image defogging is as fast in python OpenCV platform as shown in the graph.

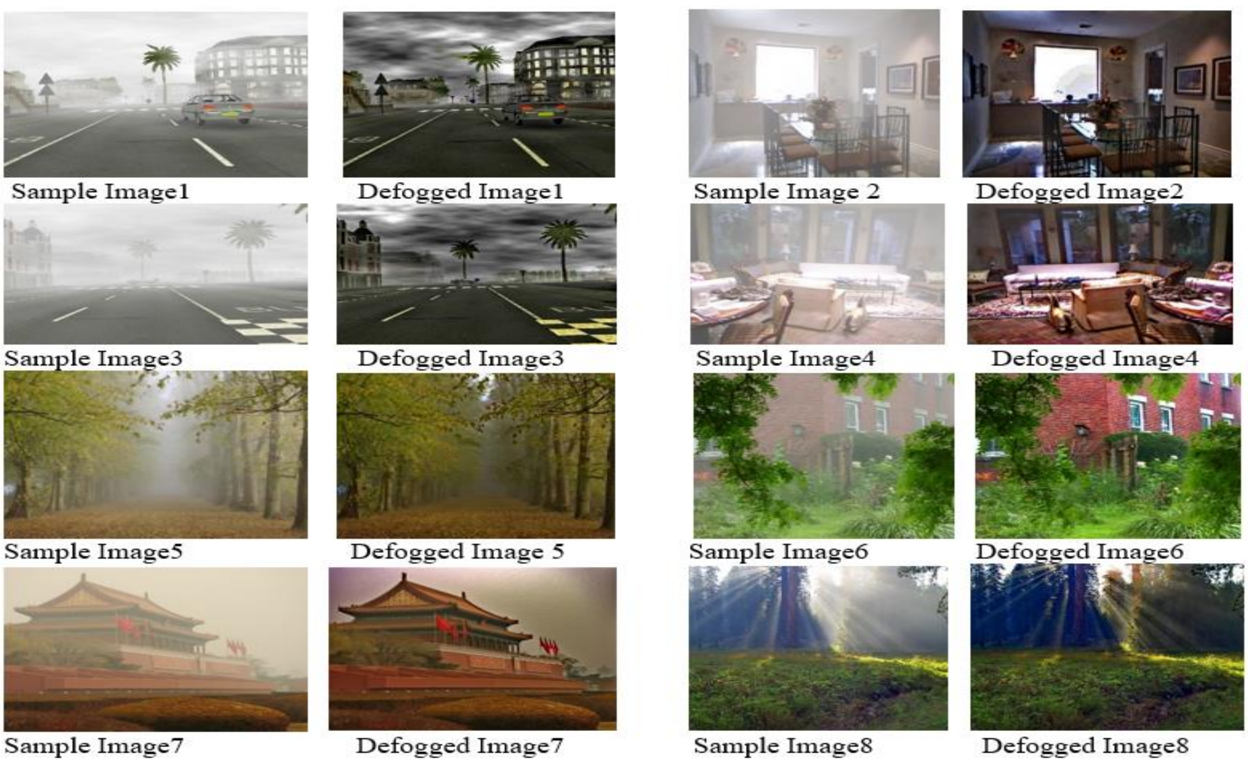

Fig7. Synthetic and real world images tested for images dehazed using in python OpenCV

Sample Image	PSNR(dB)	Time(seconds)
Sample Image1	28.05185	0.028013
Sample Image2	28.25277	0.030264
Sample Image3	28.28199	0.22638
Sample Image4	28.09839	0.020411
Sample Image5	27.91456	0.29023
Sample Image6	28.79236	0.01027
Sample Image7	27.47513	0.051011
Sample Image8	27.91867	0.072729

Table1: PSNR and defogging value in seconds

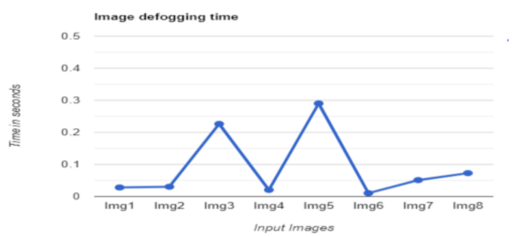

Fig8: Line graph for time taken for Image defogging

V. CONCLUSION

Our goal in the suggested system is to obtain a fog-free image from a fog image, hence we've developed a trained model for fog estimate and image defogging, firstly based on the fog relevant features a regression model is created and once the transmission and atmospheric light is estimated the defogged image is recovered from the input foggy image. Improving picture fog removal techniques can assist autonomous driving cars make better judgments in a variety of image comprehension and computer vision applications including aerial imaging, image classification, image/video retrieval, remote sensing, and video analysis recognition. The proposed system is tested with the datasets of synthetic pictures and real-world pictures as shown in the section VI.

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