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Implementation amd Analysis of Different Image Fog Removal Techniques

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Abstract **- Any outdoor photograph taken in hazy or foggy circumstances will have a markedly reduced visual quality. Furthermore, it alters the hue and brightness of the picture. Video surveillance, transportation, and remote sensing are just a few of the many computer vision uses for these pictures. In order for these apps to function flawlessly, it is crucial that the haze effect be removed from these photos. As it is, current image dehazing techniques do a decent job at making the blurry picture more legible. Nevertheless, these techniques cause a lot of artefacts, such as a halo around depth discontinuities, blocking, and color aliasing in the sky. While some solutions exist, they often come with unwanted side effects, such as blurring or an increase in saturation in the now-dehazed image. This paper aims to tackle a variety of dehazing problems, such as maintaining color in close-up views while boosting long-range sight, minimizing distortions and artefacts, and clearing away thick haze without artificially boosting distant views.**

Keywords- Haze Removal, Image Enhancement, Bilateral Filter, Median Filter, Fog Removal.

I. INTRODUCTION

Haze, fog, smoke, and other forms of atmospheric deterioration induced by particles in the air (pollutants, aerosols) are common in photographs of outdoor situations. Direct attenuation and air light are two fundamental phenomena caused by particles in the atmospheric medium absorbing and scattering light along its path from the source to the observer. Both "air light" and "direct attenuation" lessen the contrast in the scene. This causes the images we perceive through a camera or our eyes to lack sharpness, detail, and color accuracy (see Figure 1.1). As outdoor-vision applications like object recognition, tracking, navigation, and satellite imaging rely heavily on clear pictures, haze removal has become an increasingly popular and necessary feature. The problem's fuzziness presents the biggest obstacle. The scene's reflected light is muted and mixed with ambient light due to the haze's presence. In order to remove haze, the blended light must be separated so that the reflected light (and hence the scene colors) may be recovered. The blended light makes this problem technically confusing, with an endless number of possible solutions. Which option do we know to be correct? In order to effectively remove haze, we must resolve this issue.

Input hazy image — Haze removal result of our proposed approach

Figure 1.1: Haze removal from a single image by using proposed approach

To put it simply, computer vision is the study of how to teach computers to recognize objects in pictures and movies. Using AI methods, it automates many processes and draws valuable data from visual media. Smart transportation systems, video surveillance, object detection, weather forecasting, remote sensing, a radar tracking system, lane detection, etc. are only a few of the many examples of computer vision applications [1]. These programs need to "see" and evaluate the contents, hence they need high-quality input photos or videos. The visibility is reduced and these applications may fail if the weather is bad (haze, fog, rain, pollution, etc.). Low contrast, fading colors, and most crucially, limited visibility is only some of the issues with the acquired image under these conditions. Aerosols, water droplets, molecules, and other airborne contaminants can contribute to degraded images [2]. The acquired image suffers severe color distortion and loss of contrast due to these particles. Haze reduction techniques are a necessary preprocessing tool for enhancing the functionality of vision applications.

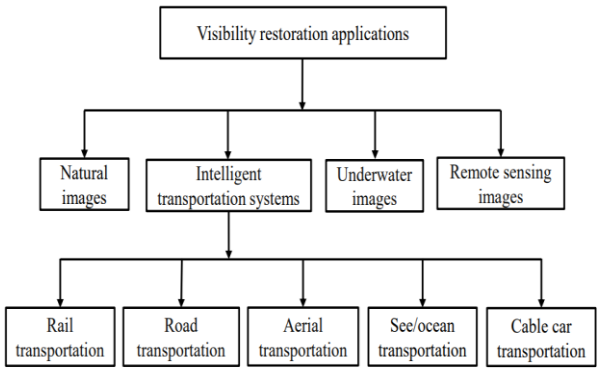

Figure 1.2: Applications of visibility restoration techniques

Figure 1.3 depicts the atmospheric scattering model (ASM), also known as the physical model of hazy picture creation, as an expression of the hazy effect in the acquired image. The reflected light from an item decreases in intensity as the distance between the viewer and the scene increases. Particle scattering also causes air to illuminate the scene, which is captured by the camera. Consequently, direct attenuation and air light make up a hazy picture. The color is distorted by direct attenuation, while visibility is diminished by air light.

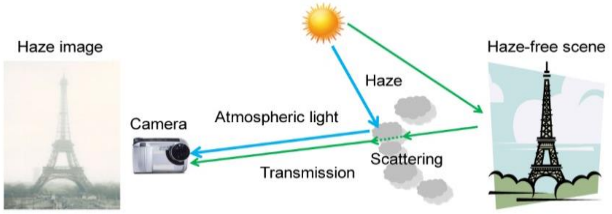

Figure 1.3: Physical model of hazy image formation

II. Literature Review

The challenge bonded to fog removal may differ. Table 1 shows the literature review of some papers:

Table 1: Comparison of various literatures present

S. No	Author	Year	Methodology	Remarks
1	K. He et. al. [3]	2011	Dark Channel Prior	It relies on the fact that most haze-free outdoor photographs have some local areas with very dim pixels in at least one colour channel.
2	H. Xu et. al. [4]	2012	Improved dark channel prior	They create a rough approximation of the transmission map using the dark channel prior, which they then blend with the grayscale in order to extract more precisely using the fast bilateral filter.
3	A. K. Tripathi et. al. [5]	2012	Bilateral filtering	To calculate ambient light and restore contrast in a scene, the proposed technique employs a bilateral filter.
4	A. Kumari et. al. [6]	2014	gamma transformation and median filtering	It is recommended to use a basic restoration-based strategy to clearing the fog.
5	Neha and R. K. Aggarwal [7]	2017	mean and Gaussian filters	As far as we can tell, the performance of bilateral filters is the best of all.
6	Gaurav Saxena et. al. [8]	2021	color channel prior based	In order to compare the efficacy of the various algorithms, standard metrics for gauging image quality are employed.

The dehazed image may suffer from various types of issues like color shift, over enhancement, structure damage or incomplete haze removal.

Under enhancement and over enhancement are common results of restoring blurry photos. When an image is under enhanced, some of the haze from the original remains. Hence, visibility is not enhanced in the way that was hoped. With dehazing, an excessive amount of enhancement might alter the original data in haze-free areas while causing a color shift in foggy areas [9]. This issue typically manifests itself in low-contrast, thick misty areas. If you apply too much dehazing, the colors will become drab and the pixels will become oversaturated.

Image dehazing algorithms should be able to enhance visibility in foggy areas without distorting the colors in such areas, while still preserving the data from haze-free parts.

III. Problem Formulation

Let us assume a hazy image I(x) with intensity values in the range of 0 to 1. The hazy/foggy weather conditions increase the intensity values of a captured image. Thus, somehow, if we manage to lower the intensity of I(x), then haze- free image J(x) can be obtained. Physical model of haze formation can be rearranged in the following form:

$$t(x) = \frac{A-I(x)}{A-J(x)}$$

Since $t(x)\in[0, 1]$, it follows from the above equation that $A-I(x) \leq A-J(x)$, and this inequality will satisfy only when $J(x) \leq I(x)\ \forall x$.

With respect to depth, degradation or visibility of the image is affected in different regions of the scene. The t(x) is an exponential function of distance. Therefore, we consider exponential distribution in the proposed work. The probability density function (PDF) of an exponential distribution is given by:

$$f_x(x) = f(x) = \begin{cases} \lambda e^{-\lambda x}, for\ x \geq 0 \\ 0, otherwise \end{cases}$$

and its cumulative distribution function (CDF) is given by:

$$P\ (X \leq x) = F_x(x) = \int_0^x \lambda e^{-\lambda x}\ dx = 1 - e^{-\lambda x}$$

where X is a continuous random variable, represents the intensity value of a pixel in a hazy image and λ is the parameter of the distribution. We have formulated a modified exponential CDF (MCDF) by introducing depth parameter d, which can effectively remove haze in a scene as follows:

$$P\ (X \leq x) = F_x(x) = 1 - e^{-\lambda x^d}$$

As can be seen in figure 1.4, the suggested technique entails four distinct phases: distant haze removal; close haze removal; contrast enhancement; and gradient fusion. The things far from the camera were dehazed by the faraway haze reduction module. As surrounding items are unaffected by the haze, the nearby haze removal module is able to restore them in their original color. Using an approach called contrast limited adaptive histogram equalization (CLAHE), we may further boost the image's local contrast. The last step involves fusing all the pictures produced in the preceding three modules into a single high-quality gradient domain image devoid of artefacts and haze [10]

One of GC's drawbacks is that it's tough to determine the best value for. A small value of is unable to clear the haze in distant areas, while a big value of does so at the expense of severe oversaturation. For this reason, we suggest a joint cumulative distribution function that may clear the haze from distant areas without affecting the colors of close ones.

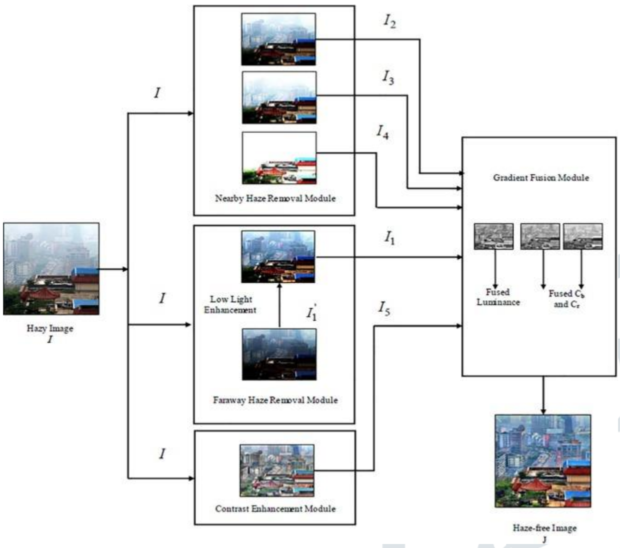

Figure 1.4: The framework of the JCDF method

IV. Result and Simulation

It has been discovered that when fog is eliminated from an image, the contrast between foreground and background decreases. For this reason, a method of boosting contrast is needed to improve readability. Histogram equalization and histogram stretching are the most often used techniques for improving visibility. The most common approach, known as histogram equalization, is used to boost a picture's contrast by gray-scale transformation, but it has the drawback of over-enhancing the image and shifting its mean brightness, leading to an artificial appearance. For the sake of maintaining visual information in the very brilliant and very dark regions, we must exercise caution to avoid clipping while doing histogram stretching. Hence, CLAHE is employed to improve the contrast of low-contrast sections rather than HE and histogram stretching, which modify the entire picture.

After processing, photos must be evaluated to see how well they have been recovered. Metrics based on the perceived quality of a picture are commonly used for this purpose. Throughout the past few decades, numerous measures for assessing the visual quality of an augmented image have been presented. When precision, speed, and utility are taken into account, each option has advantages and disadvantages. Indeed, there is no one-size-fits-all metric that specifies both the subjective and objective validity of enhancement for every possible form of image. Results of the suggested approach are evaluated in terms of both peak signal-to-noise ratio (PSNR) and execution time (t_{comp}) in this study.

Dehazing by Gamma Correction Operations: The original hazy image is first artificially under-exposed by means of a sequence of gamma-correction operations. The resulting set of multiply exposed images is merged into a haze-free result through a multi-scale Laplacian blending scheme. Five images are taken for simulation for clip range varying from 0.003 to 0.20.

Figure 1.5: Influence of the clip-range parameter *c*. (a) Road Image (b)–(f) Result of dehazing with (b) *c* = 0.003 (c) *c* = 0.005 (d) *c* = 0.010 (e) *c* = 0.015 (f) *c* = 0.020.

Single Image Dehazing by Fusion Method: The purpose of this method is to enhance photos that have been hazed. The transmission map of the input picture is typically computed in two phases using dark channel prior based dehazing algorithms. Transmission map estimation and transmission map refining are the phases. The fundamental drawback of these methods is the need to compromise restoration precision for reduced processing time. In order to maximize the dynamic range of the restored image, this methodology employs a multilayer perceptron to compute the transmission map directly from the minimum channel and a contrast stretching algorithm to stretch the original image.

Figure 1.6: Hazy road image as input and dehazed image as output

Figure 1.7: Hazy train image as input and dehazed image as output

Dehazing by Weiner Filtering: This method uses a median filtering process as part of a visibility restoration strategy. By exchanging the second minimum operator for a median operator, the proposed method improves the Dark Channel Prior [11]. The median operator uses a non-linear filtering operation to effectively minimize impulsive noise components, which does so while maintaining edge information in detail areas and allows dehazing in smooth parts.

Figure 1.8: Hazy forest image as input and dehazed image as output

Figure 1.9: Hazy train image as input and dehazed image as output

Table 2: PSNR Values (in dB)

Image Name	Case 1	Case 2	Case 3
Hazy Road	12.81	12.05	34.48
Train	18.32	19.21	39.91
Canyon	14.96	13.27	33.25
Sea	13.54	13.31	33.29

Table 3: Processing Time (in Sec)

Image Name	Case 1	Case 2	Case 3
Hazy Road	2.286	3.86	2.98
Train	2.336	2.52	4.31
Canyon	3.258	3.39	5.38
Sea	6.974	4.88	3.77

V. CONCLUSION

In order to enhance the visibility of the hazy image without distorting the recovered image, a new approach of image dehazing has been presented in this study. We have computed the peak signal-to-noise ratio, processing time, and visibility matrix using simulations for four different approaches.

The effectiveness of the proposed approach for dehazing images is demonstrated. The concept of creating artificially exposed copies of a low-quality image and merging them into an output of higher visual quality is not unique to the process of fog removal. A similar strategy might be useful for fixing other issues in picture processing, such compensating for uneven lighting. In addition, the used picture fusion strategy is a fundamental method within the discipline of multiple-exposure image fusion, and more sophisticated approaches might be investigated to further enhance performance or explore alternative applications.

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