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Various Types of Image Dehazing: A Review

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***Abstract*—** This paper aims to provide a comprehensive review of various techniques employed for haze removal. Within the realm of image processing and analysis, image dehazing stands out as a pivotal area of research. The dehazing process holds significant importance in enhancing human comprehension under conditions of low visibility. Haze, indicative of poor air quality, manifests as a visually impairing pale appearance in the atmosphere, leading to diminished visibility. This atmospheric phenomenon arises from the heightened concentration of air pollutants suspended in the air, causing scattering and absorption of sunlight. Consequently, affected images exhibit a whitened appearance with reduced contrast.

The adverse effects of haze extend across diverse applications within computer vision, notably in fields such as video surveillance and object detection. This paper is dedicated to thoroughly exploring various procedures designed to effectively eliminate haze from images. Furthermore, it critically evaluates the limitations inherent in existing methods, aiming to contribute insights into refining and advancing dehazing techniques.

***Index Terms*—** Image dehazing, Dark Channel Prior, Contrast Enhancement. Polarization.

I. Introduction

The primary objective of image processing is to enhance visualization, sharpen details, restore quality, retrieve information, and recognize patterns within an image. However, outdoor scenes often contend with adverse conditions like haze, fog, and smog, which significantly compromise image quality. Haze, specifically, poses a challenging problem by dampening contrast and altering color, rendering many applications unreliable in its presence. The detrimental impact of haze extends to underwater photography, diminishing clarity in captured images. Consequently, the mitigation of adverse weather conditions has become an indispensable facet of computer graphics.

The challenges posed by atmospheric haze are particularly pronounced in terrestrial photography, where capturing images of distant subjects necessitates the traversal of a substantial volume of heavy atmosphere. The scattering of light by haze particles results in reduced contrast and visibility. The introduction of image dehazing techniques becomes imperative to counteract these effects, as the haziness debases overall picture quality, detrimentally affecting various image processing applications.

The scattering phenomenon primarily stems from attenuation and air light. Haze attenuates light reflected from objects, which then combines with additional light present in the atmosphere. The core objective of image dehazing techniques is to enhance the reflected light component in comparison to the mixed light. Employing dehazing methodologies such as DCP, ICA, and depth map-based methods proves instrumental in improving an image's resolution and intensity. Through these techniques, the adverse impact of haze is mitigated, resulting in enhanced image quality for a myriad of applications reliant on image processing.

II. Types of Image Dehazing

There are two types of Image Dehazing:

A. Multiple Image Dehazing: In Multiple Image dehazing methodology, multiple images of a singular scene are captured. Within an image, various variables contribute to its overall composition. This approach selectively identifies and utilizes known variables while reducing the effect of unknown variables. The techniques falling under this category include:

1. Polarization-Based Method: Many images are taken with different polarization filters in this method. The fundamental principle involves capturing multiple images of the same scene at various polarization degrees. This is achieved by rotating the polarizing filter attached to the camera. However, this method is generally not very much accurate for dynamic scenes.

2. Weather Condition Based Methods: Numerous images are gathered under varying weather conditions. Initially, the approach involves discerning differences among multiple images capturing the same object. Each picture encapsulates a unique perspective owing to distinct atmospheric conditions. Although, this method has advantage in enhancing visibility, a notable drawback surfaces: it necessitates waiting for weather conditions to change, rendering it a time-consuming process.

3. Depth Map-Based Method: In this method, depth information is leveraged for dehazing. A single image is employed, presupposing the availability of a three-dimensional geometric prototype from an existing database, along with assumed knowledge of the scene's texture. This model is then aligned with the hazy image to derive the scene's depth. Although, this method shows accurate results, a drawback is its reliance on user interaction, lacking full automation.

Implementing this method demands substantial resources, which can be challenging to acquire in certain scenarios.

Figure-1 Hazy and Dehazed images [23]

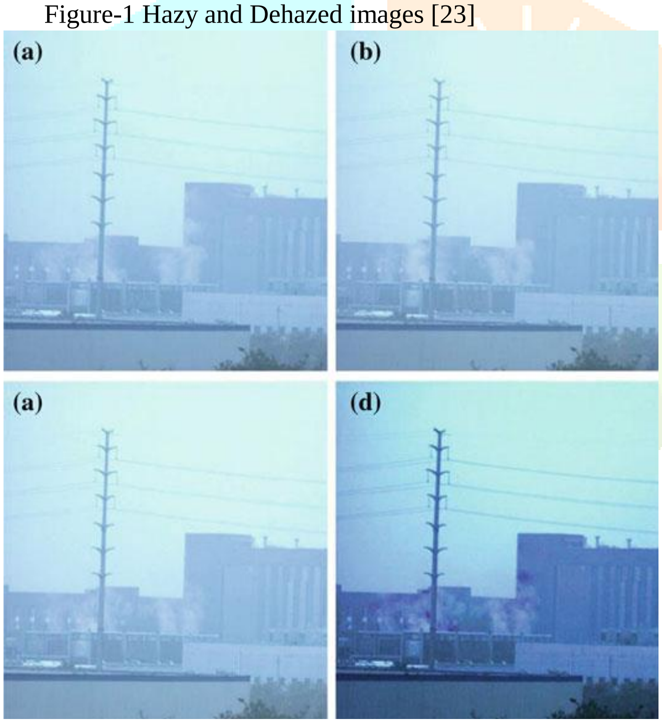

Figure-2 i) Image taken at 0 degree polarization,
ii) image taken at 45 degree polarization,
iii) image taken at 90 degree polarization,
iv) the de-hazed image [23]

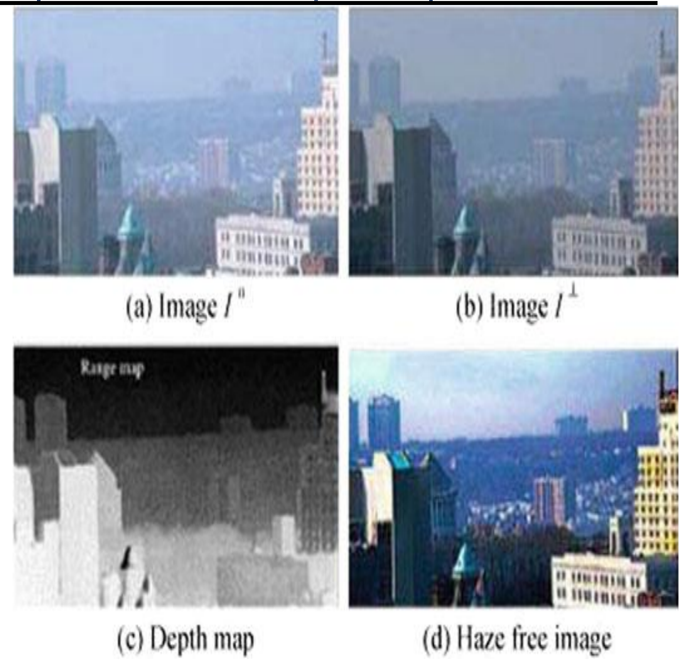

Figure-3 Dehazing using Depth Map-based method [23]

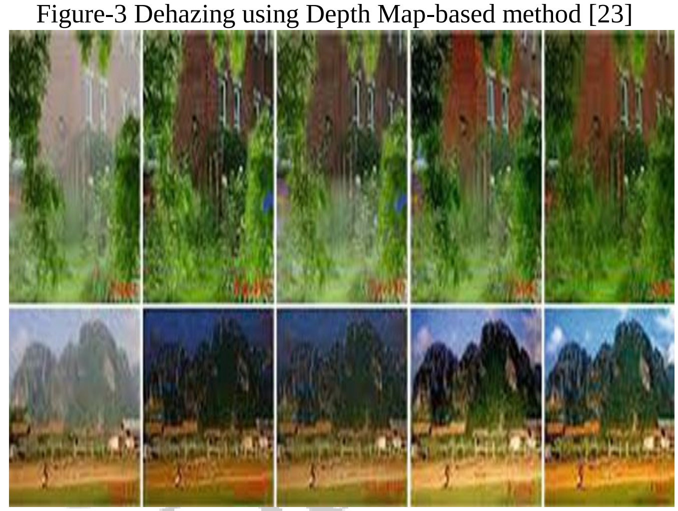

Figure-4 Images at different contrasts, dehazed image [23]

B. Single Image Dehazing Method: Differing from the multiple-image dehazing approach, this method relies on a single captured picture. All essential scene information is extracted from this lone input image. Researchers exhibit a heightened interest in this method compared to its counterpart. Following techniques may be included in this catagory:

1. Independent Component Analysis Technique: This method involves a statistical procedure where two distinct constituents of the given image are separated. It assumes that the transmission and shading of the surface are statistically orthogonal in local patches. While this process provides good result in sparse haze scenarios, it encounters limitations in dense haze conditions, leading to less effective outcomes.

Figure-5 Hazy and dehazed images [23]

2. Contrast Maximization Technique: Haze diminishes contrast, and the essence of haze removal lies in augmenting contrast. This method focuses on contrast enhancement, yet it is subject to several constraints. Notably, improvements in brightness and depth are not realized; only visibility is heightened through contrast enhancement. Consequently, the output image tends to exhibit considerable saturation, posing a significant drawback to this approach.

3. Antistrophic Diffusion Technique: This method removes haze while preserving crucial elements like edges and lines, ensuring minimal disruption to image understanding. It incorporates anisotropic diffusion to refine the air light map derived from DCP. The notable advantage of this approach lies in its flexibility, demonstrating effective performance even in scenarios with dense haze.

4. Dark Channel Prior Technique: This stands out as one of the most effective image dehazing methods. By considering the lowest intensity values and identifying the minimum among them, the dark channel is derived. This approach involves the initial calculation of atmospheric light and transmission for dehazing an image. While successful in both sparse and dense haze scenarios, it exhibits limitations when the scene image closely resembles the air light, impeding accurate atmospheric light calculation and consequently affecting the output quality.

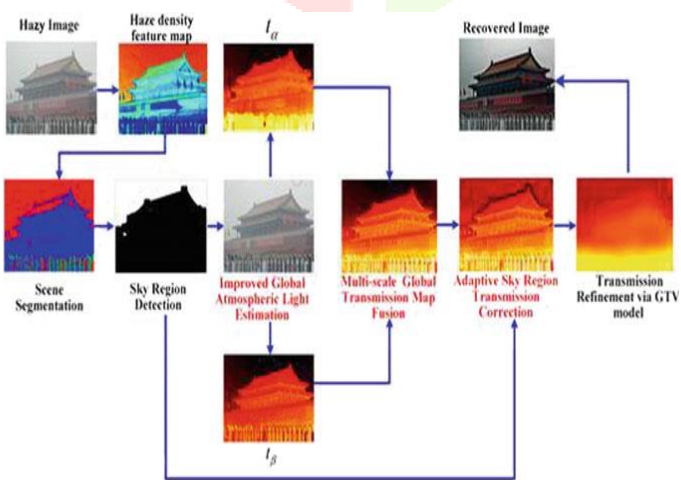

Figure-6 Dehazing using Dark Channel Prior(DCP) [23]

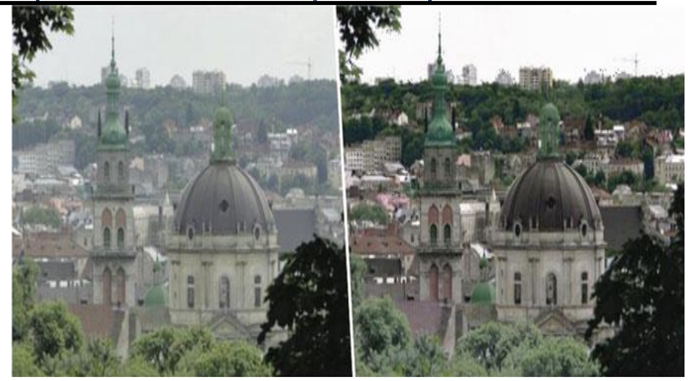

Figure-7 Hazy and dehazed images [23]

III. Literature Survey

Tarel et al. [12] proposed an algorithm for single-image dehazing based on a filtering approach. This method involves a limited number of linear operations that necessitate various frameworks for modification. The key advantage of this algorithm lies in its speed, enabling real-time application for visibility restoration in image dehazing.

He et al. [13] introduced a straightforward yet effective method, DCP, for dehazing input images. It relies on statistics derived from external non-hazy images to estimate haze transmission. However, there comes a limitation in this method whenever the air-light and surface object are closely similar, impacting its effectiveness.

Xu et al. [24] introduced an enhanced version of Dark-Channel-Prior (DCP). Their improvement involved replacing the intricate soft matting component with a quick bilateral filter, resulting in faster execution speed and heightened efficiency compared to the original algorithm.

Ullah et al. [15] contributed another refined version of DCP. In this updated Dark-Channel-Prior, both achromatic and chromatic features of image given at the input are utilized. This modification leads to further improvements in color vibrancy and contrast of the restored images, with the algorithm considering the minimum of saturation and intensity instead of RGB components.

Ansia et al. [25] introduced a method focused on contrast-based single-image dehazing. The approach involves using white balancing to neutralize color, estimating a saliency map to identify discernible regions in the image, employing morphological operators to remove specularities, and applying an intensified Contrast-Limited-Adaptive-Histogram-Equalization(i.e. CLAHE) approach to enhance color contrast. This method yields superior results, particularly effective for images with homogeneous haze.

Arora et al. [26] proposed an Integrated Dark Channel Prior (IDCP) method, which combines Dark Channel Prior (DCP),Contrast-Limited-Adaptive-Histogram-Equalization (i.e. CLAHE), and gamma correction methods. The primary goal of this algorithm is to enhance the reliability and certainty of Intelligent Transportation Systems (ITS).

Zhu et al. [27] introduced an innovative linear color attenuation prior, leveraging the variance between the saturation and brightness of pixels in hazy-image.

IV. Gaps in Literature

A haze-free image inherently exhibits distinct contrasts compared to its hazy counterpart, making image dehazing crucial for various vision applications. However, a comprehensive examination of different methods and algorithms reveals several overlooked aspects in existing research. Through a literature survey, several research gaps have come to light, including:

- Neglect of noise removal in the mentioned methods.
- Oversight of the issue of irregular illumination, which adversely impacts algorithm performance.
- Lack of efforts to integrate the methods of Dark-Channel-Prior(i.e. DCP) and Contrast-Limited-Adaptive-Histogram-Equalization(i.e. CLAHE).
- Absence of measures directed toward improving the methods of dehazing for images in applications like remote sensing.
- Insufficient attention given to the enhancement of underwater images.

Targeting the above mentioned research gaps will lead to more robust and versatile image dehazing methods, enhancing their applicability across a broader range of scenarios and applications.

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