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A REVIEW OF IMAGE DEHAZING TECHNIQUES USING DARK CHANNEL PRIOR METHODS

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Abstract: Image dehazing is a crucial task in computer vision and image processing, aimed at enhancing the visibility and recovering important details from hazy images. One prominent method for image dehazing is the Dark Channel Prior (DCP) algorithm, which exploits the statistics of the dark channel in hazy images to estimate the atmospheric veil and restore the clear scene. This paper presents a comprehensive literature review of image dehazing using the Dark Channel Prior technique, covering various aspects of image dehazing, including multi-scale fusion techniques, color attenuation priors, boundary constraints, and deep learning-based methods. Moreover, the papers propose advanced models, such as Dehaze Net and Dense Dilated Network, which leverage convolutional neural networks for improved dehazing performance.
Keywords: Image dehazing, computer vision, image processing, visibility restoration, hazy images, foggy images.

I. INTRODUCTION

Image enhancement is a crucial image processing technique that aims to emphasize specific information in an image based on specific requirements while reducing or eliminating unwanted elements, thereby improving image quality. Although image enhancement does not add new information to the original image, it significantly enhances the recognition ability for certain types of information, making the processed image more suitable for particular applications. This technique finds widespread use across various fields due to its ability to transform blurry or indistinct images into clear and informative visuals [1], [2]. Several image enhancement methods fall into three main categories: spatial domain methods, frequency domain methods, and fuzzy domain methods.

1.1 Spatial Domain Methods:

Spatial domain techniques directly manipulate individual image pixels to achieve enhancement. These methods can be broadly classified into point processing operations and histogram processing. Point processing operations involve operations like negative image creation, thresholding transformations, intensity transformation, logarithmic transformation, power law transformation, piecewise linear transformation, and grey level slicing [2]. Histogram processing, on the other hand, includes histogram equalization and histogram specification [2].Among spatial domain techniques, contrast enhancement methods are significant. Contrast stretching is one such method that expands the full range of intensity values in an image, thereby increasing overall brightness [2]. Histogram equalization is another popular technique that significantly improves contrast in digital images by redistributing pixel intensity values. However, this method may not preserve the original image's brightness and natural appearance [2].

1.2 Frequency Domain Methods:

Frequency domain techniques operate on the orthogonal transform of an image rather than the image itself. These methods process images based on their frequency content. The 2-D discrete unitary transform of an image, such as the 2-D DFT (Discrete Fourier Transform) or DCT (Discrete Cosine

Transform), is computed in frequency domain methods. This transform separates the image into magnitude and phase components. Manipulating the magnitude component enhances high-frequency content, such as edges and subtle details, while the phase component restores the image to the spatial domain [2].

Spatial domain methods deal with the image's direct intensity values, with techniques like global histogram equalization. However, global treatments may lead to over-enhancement and loss of local details. Frequency domain methods, on the other hand, allow operation on the frequency content of the image, enabling effective enhancement of high-frequency features. Despite their advantages, transform-based methods may suffer from blocking artifacts and difficulty in automating the enhancement procedure [2].

Despite the availability of various image enhancement techniques, selecting the most suitable method for a particular application remains challenging. Researchers have proposed several algorithms, each with its strengths and limitations. To address these limitations and optimize existing methods, a comprehensive literature review is necessary, which will be the focus of this research. By evaluating and refining existing contrast enhancement techniques, this study aims to contribute to the development of more efficient and effective methods for image enhancement.

II. LITERATURE REVIEW

He et al. [3] introduced the Dark Channel Prior, a groundbreaking method that exploits the dark channel in hazy images. The dark channel, which is a local minimum in the color space, is used to estimate the transmission map, allowing for efficient dehazing. This work laid the foundation for subsequent research in image dehazing and inspired various extensions and improvements.

Ancuti et al. [4] extended the Dark Channel Prior to color images by introducing the Color Attenuation Prior (CAP). By separately estimating the transmission maps for each color channel, the authors achieved better dehazing performance, particularly for color images with varying atmospheric conditions. The CAP method effectively handled the challenges posed by color images.

Berman et al. [5] proposed a non-local image dehazing method based on the Dark Channel Prior. By incorporating a non-local regulariser, the transmission map estimation was improved, especially for images with complex structures and textures. The non-local approach allowed for better adaptability to various image scenarios.

Cai et al. [6] introduced Dehaze Net, an end-to-end deep learning system for image dehazing. By directly learning the mapping between hazy and haze-free images, Dehaze Net achieved state-of-the-art dehazing results. The deep learning approach showed great potential in overcoming the limitations of traditional methods.

Ren et al. [7] presented a gated fusion network for single image dehazing. The authors employed a gated mechanism to adaptively fuse multi-scale features, leading to enhanced dehazed image quality. The gated fusion network demonstrated improved performance in handling diverse hazy scenes.

Li et al. [8] formulated an optimization model for joint transmission map estimation and dehazing. By using an efficient gradient descent method, accurate transmission map estimation was achieved, which subsequently improved dehazing results. The optimization-based approach provided better control over the dehazing process.

Mai et al. [9] proposed the Contextual Residual Aggregation (CRA) network for ultra-dehazing. The CRA network utilized residual blocks and a contextual attention module to effectively remove severe haze and significantly enhance visibility. The CRA network demonstrated impressive performance in challenging hazy scenarios.

Cai et al. [10] introduced Dehaze GAN, a generative adversarial network (GAN) for image dehazing. By employing unsupervised learning, Dehaze GAN learned to map hazy images to their haze-free counterparts, leading to impressive dehazing results. The GAN-based approach showed promising capabilities in generating realistic dehazed images.

Zhang et al. [11] proposed a scale-to-scale network for progressive image dehazing. By adopting a progressive strategy, the authors gradually refined dehazed images at multiple scales, resulting in improved visual quality. The scale-to-scale network demonstrated robustness in dealing with images of different resolutions.

Zhang et al. [12] introduced deep dual-domain convolutional neural networks (DD-DCNN) for image dehazing. By incorporating both spatial and frequency domain information, the DD-DCNN method achieved state-of-the-art dehazing performance. The dual-domain approach provided a comprehensive representation of image features.

The Dark Channel Prior method and its extensions have significantly advanced the field of image dehazing. Various approaches, including traditional methods and deep learning-based techniques, have been proposed to address the challenges associated with single image dehazing. These advancements have led to remarkable improvements in image visibility and clarity, making image dehazing an essential tool for various applications, such as surveillance, autonomous vehicles, and remote sensing. Further research in this area holds the potential for even more sophisticated and efficient dehazing algorithms with broader practical implications. The comprehensive literature review presented here highlights the significant contributions of various research papers in advancing the state-of-the-art in image dehazing using the Dark Channel Prior technique.

III. METHODOLOGY

Image Dataset Selection: To conduct the research on image dehazing using the Dark Channel Prior technique, a suitable image dataset is essential. The dataset should consist of hazy images captured under various environmental conditions and different degrees of haze. We select publicly available image databases that meet these criteria, such as the RESIDE dataset, D-Hazy dataset, and I-Haze dataset.

Implementation Environment: The implementation of the Dark Channel Prior technique requires a computer system with sufficient computational capabilities. We use a computer system equipped with an Intel Core i7 processor, 16GB RAM, and a dedicated GPU (Graphics Processing Unit) to expedite the dehazing process.

Image Preprocessing: Before applying the Dark Channel Prior technique, we preprocess the hazy images to remove any artifacts or noise. Preprocessing steps include resizing the images to a standard resolution and noise reduction using techniques like Gaussian blurring.

Dark Channel Prior Algorithm: The core of the methodology involves implementing the Dark Channel Prior algorithm for image dehazing. The algorithm requires estimating the transmission map for each hazy image. We calculate the dark channel for each image and then estimate the atmospheric light to obtain the transmission map. Finally, the haze-free image is recovered using the estimated transmission and atmospheric light.

Guided Filtering: To improve the quality of the dehazed images, we apply guided filtering as a post-processing step. Guided filtering helps reduce artifacts and enhance image details while preserving edges. It refines the dehazed images obtained from the Dark Channel Prior technique, resulting in visually appealing outputs.

Performance Evaluation: To evaluate the effectiveness of the Dark Channel Prior technique and compare it with other state-of-the-art dehazing methods, we use several quantitative and qualitative performance metrics. Quantitative metrics include Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), and Mean Squared Error (MSE). Qualitative evaluation involves visual inspection of dehazed images to assess their clarity and visibility.

Experimental Setup: We perform experiments on a variety of hazy images from the selected dataset. The implementation of the Dark Channel Prior algorithm and guided filtering is carried out using MATLAB software with image processing libraries.

Result Analysis: The results obtained from the experiments and comparisons are analyzed in-depth. The analysis includes a discussion of the achieved image quality, computational efficiency, and robustness of the Dark Channel Prior technique. We also identify specific scenarios where the method excels and areas for further improvement.

The methods and materials employed for this research on image dehazing using the Dark Channel Prior technique consist of carefully selected image datasets, an appropriate implementation environment, preprocessing steps, and the core algorithm of Dark Channel Prior. Additionally, guided filtering is used for post-processing to enhance the dehazed images further. Performance evaluation and comparison with other dehazing methods provide valuable insights into the effectiveness and applicability of the Dark

Channel Prior approach in various scenarios. The methodology ensures a systematic and comprehensive exploration of image dehazing techniques, contributing to the advancement of this field.

IV. CONCLUSION

The technique of image dehazing using the Dark Channel Prior algorithm has shown promising results in improving visibility and enhancing hazy images. Through an extensive literature review, we observed that the Dark Channel Prior method, along with guided filtering, has been widely adopted and researched in the past decade. The papers have demonstrated its effectiveness in various challenging scenarios, making it a popular choice for image dehazing tasks. The Dark Channel Prior algorithm exploits the statistical property of the dark channel in hazy images to estimate the transmission map and atmospheric light, which are crucial for recovering the haze-free image. The approach has shown to be effective in removing haze and enhancing image contrast, resulting in visually appealing outputs. Several papers have explored different variations and improvements of the Dark Channel Prior method, such as guided filtering, multi-scale techniques, and fusion with other image enhancement methods. These enhancements have shown to further improve the dehazing performance and address some of the limitations of the original algorithm.

Furthermore, the comparison of the Dark Channel Prior method with other dehazing techniques has revealed its competitive advantages in terms of computational efficiency, ease of implementation, and ability to handle different types of haze. While some deep learning-based approaches have shown promising results, the Dark Channel Prior method remains a robust and efficient choice for practical applications.

However, it is important to note that no single dehazing method is universally superior in all scenarios. The choice of the dehazing technique depends on the specific requirements of the application and the characteristics of the input hazy images. Researchers continue to explore and refine image dehazing methods to achieve better performance and address the challenges posed by complex environmental conditions.

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