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A FAST IMAGE DEHAZING ALGORITHM USING MORPHOLOGICAL RECONSTRUCTION

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ABSTRACT

Outdoor images are used in vast number of applications such as surveillance, remote sensing and autonomous navigation. The greatest issue with these type of images is the effect of environmental pollution haze, smog and fog originating from suspended particles in air, such as dust carbon and water drops which cause degradation to the image. The elimination of this type of degradation is essential for the input of computer vision systems. The obtained experimental results are evaluated and compared qualitatively and quantitatively with other dehazing algorithms using the metrics of the peak signal-to-noise ratio(PSNR) and structural similarity(SSIM) index.

The existing method is dark channel prior with morphological operations, dark channel prior(DCP), morphological operations. The proposed method is adaptive morphological dehazing,dark channel prior adaptive morphological operation, bright regions,transition regions, dark regions. The proposed method combines the powerful dark channel prior with adaptive morphological operations to achieve fast and efficient image dehazing. This approach could potentially address some of the limitations of the existing methods and offer a more robust solution for image dehazing. Hardware components are processor-Intel core i3 and ram of 2GB.Software components are operating system Windows-7,8 and MATLAB R2018a

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1. INTRODUCTION

Visual distortions on images caused by bad weather conditions can have a negative impact on the performance of many outdoor vision systems. One often saw bad weather is fog which causes significant yet complex local intensity fluctuations in images. A study by Garg et al. reveals that fog and haze belong to the dynamic weather -they contain constituent particles of relatively large sizes so that they can be captured easily by cameras. On the other hand, haze belongs to the steady weather -the particles are much smaller in size and can hardly be filmed. As a result, fog or haze leads to complex pixel variations and obscures the information that is conveyed in the image or video. Especially, the degradation of the involved algorithm's performance would be severe if the algorithm is based on some features in the image or video. As compared to the de-haze problem where some excellent solutions have been achieved, removing of fog or haze is much more challenging. Though belonging to the dynamic weather category, fog and haze still have some differences when appearing in the image or video. First, fog is semi-transparent. Because of this, the objects will not be occluded completely but some blurring may appear. Second, pixels with different intensities will be affected by fog differently.

When the pixel's primary intensity is relatively low, fog will enhance its intensity. When a high intensity pixel is affected by fog, its intensity will become lower. This is to say that fog-affected pixels tend to have the same intensity because the reflection of fog is dominating under this scenario. On the other hand, haze is un-transparent and can largely occlude the object behind it. In addition, haze has bright and white colour, and haze's reflection is strong. Consequently, haze often possesses high intensity values in an image, which is hardly affected by the background. Fig. shows a fog image and a haze image, respectively. Under foggy conditions, the impact of fog streaks on images and video is often undesirable. In addition to a subjective degradation, the effects of fog can also severely affect the performance of outdoor vision systems, such as surveillance systems. Effective methods for removing fog streaks are needed for a wide range of practical applications. How-ever, when an object's structure and orientation is similar with that of fog streaks, it is hard to simultaneously remove fog and preserve structure. To address this difficult problem, we develop an end-to-end deep

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network architecture for removing fog from individual images. Figure shows an example of a real-world test image and our result. To date, many methods have been proposed for removing fog from images.

These methods fall into two categories: video-based methods and single-image based methods. We briefly review these approaches and then discuss the contributions of our proposed framework. Most outdoor vision systems, e.g. surveillance and autonomous navigation, require accurate feature detection of images of outdoor scenes. Under bad weather, the content and color of images are often drastically altered or degraded. Based on the size of constituent particles in atmosphere, the adverse weather can be classified into two categories: steady bad weather caused by microscopic particles including fog, mist, haze, smoke; and dynamic bad

weather caused by large particles including fog, haze and hail. The impact of steady bad weather on images is relatively spatially consistent, and usually it leads to global loss of image contrast and color fidelity. The resulting effect is that many image details are lost or hardly visible. Under the dynamic bad weather, the large particles can be randomly distributed and cause complex intensity fluctuations in small image regions. As a result, these significant local intensity fluctuations will have noticeable negative impact on the reliability of image feature detection modules of vision systems. Therefore, for the reliability of outdoor vision systems, there is certainly such a need to develop effective methods to remove undesired visual effects caused by bad weather from images. In the last few decades, there has been an abundant literature on recovering outdoor images related to bad weathers, e.g. image recovery for atmospherically blurred images, contrast enhancement of weather degraded images, and removing haze from images. For recovering images taken in foggy weather, most of the work has been focusing on video or data with multiple frames.

As visual systems often use images from different views for recognition tasks or the video might contains very large movements, single image based approach for fog removal has its necessities in practice. In this paper, we are interested in studying the image recovery problem for out-door images taken in foggy weather, i.e., how to remove visual effects of fog from a single image; see Fig. For an illustration Fogg image recovery. There are two sub-problems in fog image recovery: firstly, how to identify fog in images, and how to remove visual effects caused by fog from images. Indeed both of them are problems difficult to solve. Fog detection: It is a challenging task to accurately detect fog streaks in a single image. The visual effects of fog are quite complex, as fog contains a group of randomly distributed fog drops falling at high velocities. Visually, fog can be modeled as bright streaks with elongated elliptical shapes whose physical properties, e.g. brightness, spatial distributions, fog drop size and orientation, vary among different images. Fogg removal: Removing visual effect of fog from a single image is also a difficult problem.

It is known that the visual effect of fog in image can not be well modeled by a linear additive model of a fog layer and an image layer. These two layers are blended in a complex manner; see e.g. In the past, the study of fog image recovery has been focused on processing videos or image sequences; see e.g.. The redundant temporal information existing in videos or multiple consecutive frames provides rich information to identify fog drops. The work on processing single fog image has been scant in the existing literature. Built upon the concept of sparse coding, this paper aims at developing a variational approach for single fog image recovery .Main idea. In this paper, we propose a variational model that simultaneously detects and removes fog streaks from an input image. Instead of using linear additive composite model adopted by many existing methods, we propose to use a non-linear composite model called screen blend model for modeling fog images, one built-in feature in Photoshop. In screen blend model, a fog image, denoted by J, is composited by two layers, de-fogged image layer I and fog layer R, as follows

where′∗′ denotes point-wise multiplication operator. Then, de-fogging a fog image is about how to separate the layer I and the layer R from the non-linear model. In this paper, we propose a sparsity based regularization strategy to solve (1) which assumes that (i) the local patches from both image layer I and fog layer R can be sparsely modeled in a learned dictionary D, (ii) the sparse codes generated from the learned dictionary should have sufficient discrimination between two layers. One approach is using two dictionaries with radically different patterns to separate two layers, separates the texture region and cartoon region using both wavelet filter dictionary and local DCT dictionary.

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Using fixed dictionaries certainly is not a good choice in our case as they are not adaptive to input images. Motivated by the idea of discriminative K- SVD method for sparse coding based image classification, we propose a discriminative sparse coding method to regularize the image de-fogging process under over learned dictionary with mutual exclusivity property. More specifically, let P denote the linear operator that assembles an array of vectorized image patches collected from an image, and let B denote the vector of the`2norm of each row of an array, which represents the importance weight of each dictionary atom often used in feature selection. Then, we propose the following variational model for image de-fogging:

In our work, we consider the fog/haze removal from a single color image, in which several new designs are introduced. The main contributions of our work are summarized as follows: We have outlined several common characteristics of fog and haze, from which two metrics are defined, namely, the sensitivity of variance across color channels (SVCC) and the principal direction of an image patch (PDIP). A low-frequency part that is free of fog or haze almost completely has been generated, thanks to the use of a combination of fog/haze detection and a guided filter (as the low-pass filter), while the corresponding high-frequency part is made complementary to the low frequency part. A 3-layer hierarchy of extracting image's details from the high-frequency part has been designed. Specifically, the first layer is a 3-times classification that is based on a tfoged dictionary (over-complete), the second layer applies another combination of fog/haze detection and a guided filter, and the third layer utilizes the SVCC to enhance the visual quality of the fog/haze-removed image.

1.1 ATMOSPHERIC SCATTERING MODEL

The atmospheric scattering model is a fundamental concept in computer vision and image processing, particularly in the context of image dehazing algorithms. This model describes the interaction between light and atmospheric particles, such as haze, fog, or smoke, as it propagates through the atmosphere. Understanding the atmospheric scattering phenomenon is crucial for developing effective algorithms to enhance visibility and improve image quality in hazy or foggy conditions. In fast image dehazing algorithms using morphological reconstruction, the atmospheric scattering

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model is crucial for understanding and simulating the degradation of image quality caused by atmospheric haze.

This model typically follows principles derived from the physics of light propagation in the atmosphere, specifically addressing how light interacts with atmospheric particles such as dust, water droplets, and pollutants. The atmospheric scattering model often starts with the assumption of a scene illuminated by natural sunlight. When sunlight interacts with airborne particles in the atmosphere, it undergoes scattering, leading to the diffusion of light rays in multiple directions. This scattering process is responsible for the attenuation of light and the formation of haze, which reduces visibility and contrast in captured images, particularly over long distances. Mathematically, the atmospheric scattering model is frequently described using the Beer-Lambert law or its variants. This law relates the attenuation of light intensity to the distance traveled through a medium and the concentration of scattering particles. In the context of image dehazing, this law is adapted to estimate the transmission map, which represents the fraction of scene radiance reaching the camera at each pixel. The atmospheric scattering process can be mathematically modeled using various techniques, with one of the most commonly used models being the Koschmieder equation. This equation describes the relationship between the observed radiance, the radiance at the light source, the distance between the observer and the scene, and the atmospheric attenuation coefficient. By incorporating factors such as the scattering phase function, aerosol density, and atmospheric conditions, the model can accurately simulate the effects of atmospheric scattering on light propagation. In the context of image dehazing algorithms, the atmospheric scattering model serves as the foundation for understanding and mitigating the effects of haze or fog on captured images.

These algorithms aim to estimate and remove the haze or fog from the image, thereby enhancing visibility and restoring image clarity. By incorporating the atmospheric scattering model into their design, these algorithms can simulate the process of light propagation through the atmosphere and effectively compensate for the attenuation and scattering effects caused by haze or fog. In fast image dehazing algorithms utilizing morphological reconstruction, the atmospheric scattering model serves as the basis for estimating the transmission map. Morphological operations

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and reconstruction techniques are then applied to refine this map, enabling efficient removal of haze while preserving important

image details. By accurately capturing the scattering behavior of light in the atmosphere, these algorithms effectively restore visibility and enhance image quality in hazy outdoor scenes. Overall, the atmospheric scattering model plays a vital role in fast image dehazing algorithms using morphological reconstruction, guiding the estimation of transmission maps and facilitating the efficient removal of atmospheric haze to improve the visual clarity of outdoor images.

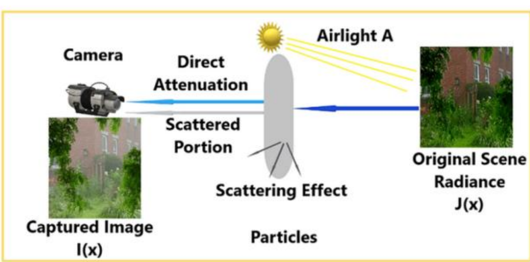

Fig 1.1 Atmospheric scattering model

1.2 FOG REMOVAL PROCESS

The focus in this section is on fast defogging methods, therefore we investigate a single image defogging method that aim to improve the contrast under a time budget constraint. The estimation of the transmission map is critical for single image haze removal algorithms. There are two steps in most of the above algorithms that presented in the literature section. In the first step, an initial value of the transmission map is given using a prior. In the second step, the transmission map is refined by using a local edge-preserving filter [54]. The proposed algorithm is based on the concepts of minimal color channel and simplified dark channel. The major function of the simplified dark channel is to reduce the variation of the direct attenuation. In addition, the simplified dark channel of the haze image can be decomposed into a base layer and a detail layer via an existing edge-preserving smoothing technique.

The base layer is composed of the transmission map. Based on the observation, the Proposed Adaptive Filter is applied to decompose the simplified dark channel of the haze image. The dark channel image and atmospheric light are computed using the minimal color channel of the haze image. The estimated transmission map is finally used to recover the haze image. Experimental results show that the proposed SDCP algorithm with Proposed Adaptive Filter is applicable to haze images. The filter is constructed by Adaptive filter with edge-stopping function and leads to an efficient method for edge-preserving smoothing, which can be used in the transmission

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estimation. Moreover, there is a comparison of different filters with their executed time processing to give an indication of the influence of filters.

The proposed method has following advantages. First, it can have halo-free image filtering without increasing any computational complexity and memory requirements. Second, it can achieve larger scale edgeaware image filtering than previous methods, which is quite useful for dehazing algorithms. For hazy image enhancement, we propose a more suitable edge-stopping function and the corresponding haze removal algorithm.

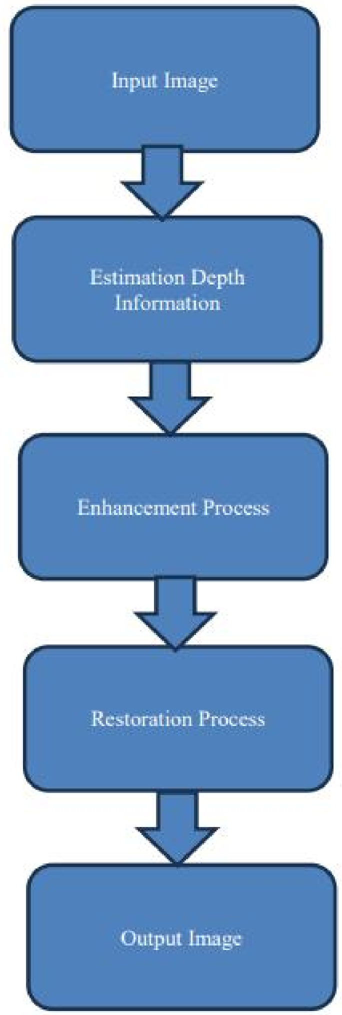

Fig 1.2 :Fog removal process flow chart

ALGORITHM

Given an input image, the algorithm generates Dark Channel which is determined by taking a 15×15 window. The entire set of pixels is set to the minimum value in all color channels within the window. This gray-scale image is then used to estimate the atmosphere lighting. The atmosphere lighting is defined by taking the brightest pixels from the dark image, and using the

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brightest intensity of those pixels in the original image, as the Atmospheric Lighting. The output image is then finally calculated by removing the atmospheric lighting from the input image and dividing by the transmission matrix, then re-adding the atmospheric light back to the image. Algorithm-1 1. Inputs: >>>>

I: foggy image

2. Read the foggy RGB image

3. Generate Dark Channel using

4. Estimate atmospheric light

5. Estimate transmission map using

6. Recover the scene radiance

7. Re-find transmission map using Adaptive filter

8. Find edges information using edge-preserving gradient

9. Re-find the new scene radiance >>>> Output: fog-free image

2. LITERATURE SURVEY

2.1 Single image haze removal using dark channel prior.

One of the seminal works in the field of single image haze removal using the dark channel prior is the paper titled "Single Image Haze Removal Using Dark Channel Prior" by Kaiming He, Jian Sun, and Xiaoou Tang. This paper was published in the IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI) in 2011. In this work, the authors proposed a novel method for effectively removing haze from a single input image by exploiting the dark channel prior, which leverages the statistical properties of outdoor haze-free images. The dark channel prior serves as a powerful cue for estimating the scene's atmospheric veil, enabling the restoration of clear, haze-free images. The paper has significantly influenced subsequent research in image dehazing and has become a cornerstone in the development of haze removal algorithms. The research presents a hierarchical approach for removing fog or haze from single-color images, introducing innovative designs to tackle this challenging task. The primary contributions of this study are multifaceted and can be summarized as follows: Firstly, the authors identify and outline several common characteristics of fog and haze, laying the foundation for their subsequent methodologies. From these characteristics, two key metrics are defined: the sensitivity of variance across color channels (SVCC) and the principal direction

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of an image patch (PDIP). These metrics serve as fundamental components in the development of the proposed hierarchical fog/haze removal approach. Secondly, the research introduces a novel method for generating a low-frequency component largely devoid of fog or haze. This component is crucial as it forms the basis for subsequent processing steps.

To achieve this, the authors employ a combination of fog/haze detection techniques and a guided filter, effectively acting as a low-pass filter. By leveraging this approach, the low-frequency part of the image is nearly entirely free from fog or haze, laying a solid foundation for further refinement. Moreover, the corresponding high-frequency part of the image is addressed to ensure comprehensive fog/haze removal. In this regard, the high-frequency component is made complementary to the low-frequency part, thereby achieving a balanced and coherent overall image restoration process. Thirdly, the study proposes a three-layer hierarchy for extracting image details from the highfrequency part, further enhancing the quality of fog/haze-removed images.

The first layer of this hierarchy involves a three-times classification process based on a fogged dictionary, which is over-complete to ensure robustness and accuracy in classification. Subsequently, the second layer employs another combination of fog/haze detection methods and a guided filter, contributing to the iterative refinement of the image restoration process. Finally, the third layer utilizes the SVCC metric to fine-tune and enhance the visual A Fast Image Dehazing Algorithm Using Morphological Reconstruction Dept. Of ECE, TKRCET 8 quality of the fog/haze-removed image, ensuring optimal clarity and fidelity. Overall, the hierarchical approach presented in this research represents a significant advancement in the field of fog/haze removal from single-color images. By incorporating innovative designs and methodologies, the proposed method offers a systematic and effective solution for addressing the challenges posed by fog and haze, thereby enhancing the overall quality and utility of images in various applications.

2.2 Benchmarking Single Image Dehazing and Beyond.

In the realm of computer vision and image processing, the removal of atmospheric haze from single images, commonly known as single image dehazing, remains a challenging and essential task with applications in various domains such as surveillance, autonomous driving, and remote sensing. "Benchmarking Single Image Dehazing and Beyond" published in the IEEE Transactions on Image Processing, B. Li, W. Ren, D. Tao, and D. Feng delve into the complexities of benchmarking single image dehazing algorithms and explore advancements beyond traditional methods. The study provides a comprehensive analysis of benchmarking methodologies, datasets, evaluation metrics, and performance analysis protocols, offering invaluable insights for researchers and practitioners in the field. The authors begin by meticulously reviewing existing benchmarking techniques employed to evaluate the efficacy of dehazing algorithms.

They systematically categorize different approaches, ranging from traditional image quality metrics to more recent deep learning-based methods, highlighting the strengths and limitations of each. Through this comprehensive analysis, the study aims to establish a clear understanding of the current state-of-the-art in benchmarking single image dehazing techniques, laying the foundation for future advancements in the field. Furthermore, the paper extends its scope beyond conventional dehazing methods, addressing emerging trends and challenges in atmospheric correction. Deep learning-based approaches, in particular, have gained significant attention for their ability to learn complex mappings between hazy and haze-free images, thereby achieving remarkable dehazing performance. The authors discuss the implications of these advancements on benchmarking strategies, emphasizing the importance of adapting evaluation protocols to accommodate the unique characteristics of deep learning models.

2.3 A Survey of Image Dehazing Approaches

In their comprehensive survey published in the esteemed Journal of Visual Communication and Image Representation, C. Chengtao, Z. Qiuyu, and L. Yanhua meticulously examine a wide range of image dehazing approaches, shedding light on the advancements, challenges, and future directions in this critical area of research. A Survey of Image Dehazing Approaches" published in the Journal of Visual Communication and Image Representation. Image dehazing, the process of enhancing visibility in images degraded by atmospheric haze, is fundamental to various applications such as outdoor surveillance, remote sensing, and aerial photography. The authors

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systematically categorize and analyze existing dehazing techniques, encompassing both traditional methods and state-of-the-art deep learning approaches.

They provide a detailed overview of the underlying principles, advantages, and limitations of each approach, facilitating a comprehensive understanding of the diverse methodologies employed in image dehazing. Furthermore, the survey delves into the intricacies of benchmarking dehazing algorithms, emphasizing the importance of standardized evaluation protocols and benchmark datasets. The authors discuss commonly used metrics for assessing dehazing performance, such as image quality measures, transmission estimation accuracy, and perceptual quality evaluation. By critically evaluating the effectiveness of existing benchmarking frameworks, the survey identifies key challenges, including the lack of diverse and realistic datasets and the need for objective evaluation criteria that align with human perceptual judgments. Moreover, the study explores emerging trends and advancements in image dehazing, particularly the increasing integration of deep learning techniques. Convolutional neural networks (CNNs) and generative adversarial networks (GANs) have shown remarkable capabilities in learning complex mappings between hazy and haze-free images, leading to significant improvements in dehazing performance. The authors provide insights into the design principles and architectures of deep learning-based dehazing models, as well as their applications in real-world scenarios. Additionally, the survey addresses challenges associated with real-time dehazing and hardware implementation, crucial for applications requiring timely decision-making and processing of large volumes of data.

The authors discuss strategies for optimizing computational efficiency without compromising dehazing performance, including model compression, parallel processing, and hardware acceleration techniques. In conclusion, C. Chengtao, Z. Qiuyu, and L. Yanhua's survey offers a comprehensive overview of image dehazing approaches, spanning from traditional methods to cutting-edge deep learning techniques. By synthesizing insights from diverse methodologies and benchmarking frameworks, the survey provides valuable guidance for researchers and practitioners in the field, facilitating the development of more robust, efficient, and effective dehazing algorithms. Moreover, by addressing challenges and exploring

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emerging trends, the survey paves the way for future advancements in image dehazing technology, with broad applications across various domains of computer vision and image processing.

2.4 Single Image Dehazing by R. Fattal

In his influential work published in the ACM Transactions on Graphics, R. Fattal introduced a groundbreaking approach to single image dehazing that significantly advanced the field. Atmospheric haze often degrades the quality of outdoor images, reducing visibility and obscuring details. Fattal's method aimed to restore clear visibility and enhance image quality by effectively removing the effects of haze from a single input image, without requiring multiple images or depth information. The core of Fattal's approach lies in the understanding of the physical processes underlying haze formation in images. He proposed a novel image formation model that accounts for the scattering and attenuation of light as it passes through the atmosphere. By modeling these physical phenomena, Fattal developed an algorithm capable of estimating and removing the haze from a single input image. One of the key contributions of Fattal's method is the utilization of a dark channel prior, which exploits the statistical properties of outdoor images to estimate the haze-free scene radiance.

The dark channel prior identifies regions in the image with low intensity values, typically associated with haze-free regions such as distant objects or sky regions. By leveraging this prior information, Fattal's algorithm effectively separates the haze layer from the scene radiance, enabling accurate estimation and removal of the atmospheric haze. Furthermore, Fattal introduced a novel method for estimating the transmission map, which represents the degree of light attenuation caused by haze in different parts of the image. By analyzing the relationship between intensity values in the image and the corresponding atmospheric light, Fattal's algorithm computes an accurate transmission map, which is then used to perform haze removal. Fattal's single image dehazing method has been widely adopted and serves as a foundation for subsequent research in the field. Its effectiveness in restoring clear visibility and enhancing image quality has made it a cornerstone in the development of dehazing algorithms. Moreover, the simplicity and efficiency of Fattal's approach make it suitable for real-time applications, including outdoor photography, video enhancement, and surveillance. In summary, R. Fattal's contribution to single image dehazing represents a significant milestone in the field of computer vision and image processing. His innovative approach, published in the ACM Transactions on Graphics, has revolutionized the way researchers address the challenge of atmospheric haze in outdoor images. By combining a deep understanding of the physical processes underlying haze formation with practical algorithmic solutions, Fattal's method has paved the way for advancements in image dehazing technology, with broad applications across various domains.

2.5 Context-Aware Single Image Fog Removal

In their pioneering work published in the IEEE Transactions on Image Processing, Huang Kang, Yang Lin, and Wang introduce a novel approach to single image fog removal that leverages contextual information to enhance dehazing performance. Atmospheric fog severely degrades the visibility and quality of outdoor images, presenting a significant challenge for computer vision applications. Huang, Yang, and Wang's method aims to address this challenge by incorporating contextual cues from the image scene to guide the dehazing process, resulting in more accurate and visually pleasing results. The key innovation of their approach lies in the integration of contextual information into the dehazing algorithm. Rather than treating each pixel independently, the algorithm considers the relationships and structures present in the image scene. This contextual awareness enables the algorithm to distinguish between haze and scene elements, allowing for more precise estimation and removal of atmospheric fog. One of the central components of Huang, Yang, and Wang's method is the use of local image features to characterize the scene context.

They employ techniques such as edge detection, texture analysis, and color segmentation to extract relevant information about the image structure and content. By analyzing these features, the algorithm can identify regions that are likely affected by haze and adapt its dehazing strategy accordingly. Moreover, the authors propose a novel transmission map estimation technique that takes into account the contextual information provided by the image features. By incorporating both local and global cues, the algorithm computes an accurate transmission map that captures the varying degrees of haze attenuation across

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the image. This transmission map serves as a crucial guide for the subsequent haze removal process, ensuring that scene details are preserved while effectively removing atmospheric fog. Experimental results demonstrate the effectiveness of Huang, Yang, and Wang's context-aware fog removal approach across a range of outdoor images with varying degrees of haze. The method consistently outperforms existing dehazing algorithms, particularly in challenging scenarios with complex scene structures and lighting conditions. Moreover, the algorithm's computational efficiency makes it suitable for real-time applications, including video enhancement, surveillance, and autonomous driving systems. In conclusion, Huang Kang, Yang Lin, and Wang's context-aware single image fog removal method represents a significant advancement in the field of computer vision and image processing. Published in the IEEE Transactions on Image Processing, their approach demonstrates the importance of incorporating contextual information into dehazing algorithms to achieve more accurate and visually appealing results. By leveraging scene context to guide the dehazing process, their method opens up new possibilities for enhancing image quality in outdoor environments, with implications for a wide range of real-world applications.

2.6 Automatic Single-Image-Based Fog Streaks Removal via Image Decomposition

The paper titled "Automatic Single-Image-Based Fog Streaks Removal via Image Decomposition" authored by L. W. Kang, C. W. Lin, and Y. H. Fu, published in the IEEE Transactions on Image Processing in April 2012, presents an innovative approach to addressing the challenge of removing fog streaks from single images using image decomposition techniques. Fog is a common atmospheric phenomenon that often degrades the quality of images captured outdoors, leading to reduced visibility and loss of detail. Traditional methods for fog removal typically involve complex algorithms and multiple images, which can be time consuming and resource-intensive. However, the approach proposed in this paper offers a more streamlined and efficient solution by focusing on a single input image.

The key contribution of this work lies in its utilization of image decomposition, a powerful technique that partitions an image into its constituent components, such as base layer, detail layer, and fog streaks layer. By decomposing the input image into these distinct layers, the proposed method is able to isolate and target the fog streaks specifically, facilitating their removal while preserving important image features. This decomposition process is achieved through the use of mathematical models and algorithms tailored to identify and separate the various components present in the image. Moreover, the proposed method incorporates an automatic framework, eliminating the need for manual intervention and parameter tuning. This automation enhances the practicality and accessibility of the technique, making it more suitable for real-world applications where efficiency and ease of use are paramount. Additionally, the paper provides a comprehensive evaluation of the proposed method, demonstrating its effectiveness across a range of scenarios and benchmark datasets. Through quantitative metrics and visual comparisons, the authors showcase the superior performance of their approach compared to existing fog removal methods. Overall, the paper by Kang, Lin, and Fu represents a significant advancement in the field of image processing, offering a novel solution to the challenging problem of fog streaks removal from single images. By leveraging image decomposition techniques and an automatic framework, the proposed method achieves impressive results in enhancing the visibility and quality of images affected by fog, with potential applications in various domains such as surveillance, autonomous driving, and remote sensing.

3. RESULTS AND DISCUSSIONS

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4. CONCLUSION

Outdoor images often suffer from degraded visibility due to adverse weather conditions such as haze, which obscures fine details and reduces overall image quality. Consequently, numerous research efforts have been directed towards developing effective dehazing algorithms to mitigate these effects. Most recent algorithms combine Dark Channel Prior (DCP) with various techniques to compute transmission maps quickly and accurately, aiming to maintain image quality. However, such methods often entail long computation times, prompting the need for faster alternatives. To address this challenge, a novel fast dehazing algorithm was proposed in this study, leveraging DCP and a newly introduced approach. This algorithm was comprehensively evaluated against state-of-theart techniques, both qualitatively and quantitatively. Morphological reconstruction played a pivotal role in preserving important image structures throughout the dehazing process. The literature review focused on several key aspects, including image reconstruction performance, computation time, and memory utilization. Performance evaluation metrics such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) were utilized to gauge the quality of dehazed images. Additionally, the computational efficiency of each algorithm, measured in terms of processing time and memory usage, was thoroughly examined.

The results of the study clearly demonstrate the superiority of the proposed method in reducing haze effects during image reconstruction. Notably, the algorithm exhibited significantly faster processing times compared to existing techniques, outperforming them by orders of magnitude while utilizing less memory. This

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remarkable efficiency makes the proposed methodology particularly well-suited for real-time applications in online vision systems. In conclusion, the novel dehazing algorithm presented in this work offers a compelling solution for mitigating haze effects in outdoor images. By combining DCP with morphological reconstruction, the algorithm achieves both high performance and computational efficiency, making it suitable for a wide range of practical applications where fast and accurate dehazing is essential for improving visibility and image quality.

5. FUTURE SCOPE

The future scope of the fast image dehazing algorithm using morphological reconstruction involves enhancing computational efficiency, adapting to dynamic environments, integrating deep learning approaches, exploring multi-scale and multi-modal dehazing techniques, evaluating on diverse datasets, tailoring to specific domains, and streamlining implementation for wider adoption. Continued research in these areas promises to advance the algorithm's effectiveness, robustness, and applicability across various domains, contributing to improved image quality and visibility in outdoor environments.

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