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AN EFFICIENT DE-HAZING AND ENHANCEMENT METHOD FOR UNDER WATER AND LOW LIGHT IMAGES

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Abstract

It is difficult to simultaneously improve the clarity of images taken underwater and in low light because they have different properties. To depict a water photo and a dark picture on an equal footing, this study proposes an enhancement method and dehazing approach. In addition to these techniques, several others such as guided filtering are used for MSRCR color recovery. When it comes to dealing with color distortion, loss of edge features, and low light situations, white balance fusion global guided image filtering (G-GIF) is very effective. Results from the experiments show that this technique can solve exposure problems in pictures but also preserve better the color saturation as well as enhance the texture features of edges in comparison to other methods leading to good visual appearance.

Keywords: Global guided image filtering (G-GIF) , DE-HAZING, Low Light Images

1.Introduction

Enhancing underwater and low-light images is challsenging due to visibility issues. Dark channel prior-based algorithms offer a solution by targeting dark areas indicative of haze or fog, improving image quality. They preserve details while removing haze, enhancing colour and contrast. These algorithms show promise for transforming dull images into vibrant ones, sparking further research in image processing.

1.1 Challenges in Low Light Imaging

Underwater and low-light imaging contexts present formidable obstacles that substantially compromise the fidelity of captured images. These challenges stem from the intrinsic characteristics of the imaging environments and the complex physical phenomena governing light propagation and interaction within these domains.

In underwater imaging, a primary hurdle is the rapid attenuation of light as it traverses through water. The differential absorption and scattering of light by water molecules result in a spectral shift, manifesting as a characteristic bluish or greenish hue in underwater imagery. Furthermore, suspended particulate matter induces backscattering, thus diminishing image clarity and contrast. Compounding these challenges are the presence of suspended particles and marine organisms, which introduce image noise, blur, and occlusions. These entities exacerbate light scattering effects, further compromising image clarity and contrast. Conversely, low-light imaging scenarios are characterized by a scarcity of ambient illumination. Consequently, captured images exhibit pronounced noise, diminished contrast, and color aberrations. The low signal-to-noise ratio prevalent in such conditions yields images characterized by granularity and poor discernibility of fine details and textures.Additionally, in low-light environments, challenges arise from the camera sensor's struggle to accurately capture colour information, resulting in colour fidelity issues or desaturation. This is particularly problematic in contexts where precise colour rendition is imperative, such as in forensic analysis, medical diagnostics, or artistic endeavours.

Both underwater and low-light imaging scenarios are susceptible to non-uniform illumination, wherein certain regions of the scene exhibit uneven brightness levels. Such disparities lead to overexposed or underexposed areas in captured images, compromising overall visual coherence and aesthetic appeal.

Motivation and objectives of the research

Research into de-hazing and enhancing underwater and low-light images is driven by their broad applicability across fields like marine biology, archaeology, security, and art. Clear imagery is vital for scientific understanding, exploration, and creative expression in challenging environments. Objectives include developing effective techniques tailored to underwater and low-light conditions. This involves exploring advanced image processing algorithms such as dark channel prior and Retinex-based methods. The goal is to maintain natural colors, high contrast, and sharp details in enhanced images, crucial for accurate analysis and artistic representation. Additionally, optimizing computational efficiency for real-time applications is essential. Achieving these objectives promises to advance knowledge and capabilities across various domains, facilitating scientific discoveries, enhancing security measures, and enabling new creative possibilities in imaging.

2.Scope and contributions of the paper

This paper focuses on improving the visual quality of images taken in challenging underwater and low-light environments. It tackles issues like haze, turbidity, colour distortions, and low contrast that commonly affect such images. The research covers two main stages: dehazing and enhancement. In the dehazing stage, techniques like multi-scale retinex colour recovery (MSRCR) and guided filtering are used to remove haze and turbidity while preserving essential details and colours. The enhancement stage involves methods such as white balance fusion, guided image filtering (G-GIF), and dark channel prior-based algorithms to address challenges like dim lighting and loss of detail. The paper contributes by integrating these stages into a unified framework and by introducing novel modifications and optimizations to existing techniques. Extensive experiments are conducted using a comprehensive dataset of underwater and low-light images to evaluate the effectiveness of the proposed methods. Through these efforts, the paper aims to advance our understanding and capabilities in processing images in challenging environments, with potential applications in various fields including marine biology, archaeology, environmental monitoring, security, surveillance, and artistic endeavours.

3.Previous Works

1. Non-local image de-hazing Berman D et.al (2016)

In their work published in the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, Berman et al. delve into the realm of non-local image de-hazing techniques. They present novel methodologies aimed at enhancing visibility in challenging environments such as underwater and low-light conditions, leveraging advanced image processing algorithms.

2. Variational approach for the fusion of exposure bracketed pairs. Bertalmío M, Levine S (2013).

Bertalmío and Levine introduce a variational approach for merging exposure bracketed image pairs in their contribution to the IEEE Transactions on Image Processing. Their method offers promise in augmenting the quality of images captured in underwater and low-light scenarios by amalgamating multiple exposures through a variational framework.

3. Underwater image enhancement by wavelength compensation and dehazing. Dai CG et al. (2019)

Chiang and Chen present techniques for underwater image enhancement in their study published in the IEEE Transactions on Image Processing. Focusing on wavelength compensation and dehazing methods, their work seeks to ameliorate visibility and image quality in underwater settings.

4. Dual-purpose method for underwater and low-light image enhancement via image layer separation. Dai et al. (2017)

Dai et al. propose a dual-purpose method for enhancing underwater and low-light images by means of image layer separation, as detailed in their publication in IEEE Access. Their approach aims to enhance visibility and quality in visually challenging conditions by separating image layers.

5. Underwater image dehaze using scene depth estimation with adaptive colour correction. Ding et al. (2020)

Ding et al. introduce a method for underwater image dehazing based on scene depth estimation and adaptive colour correction techniques, as outlined in their paper presented at the IEEE OCEANS Aberdeen conference. Their approach contributes to improved visibility in underwater imaging applications.

6. Underwater depth estimation and image restoration based on single images. Drews-Jr et al. (2016)

Drews-Jr et al. propose techniques for underwater depth estimation and image restoration using single images in their work published in the IEEE Computer Graphics and Applications journal. Their methods offer solutions for enhancing underwater image quality and visibility.

7. Low-light image enhancement with semi-decoupled decomposition. Li YJ (2019)

Hao et al. (2017) discuss a method for enhancing low-light images using semi-decoupled decomposition techniques in their work published in the IEEE Transactions on Multimedia. Their approach may hold implications for improving visibility in low-light underwater conditions. Liu et al. (2018), Lu WJ et al. (2019).

4.Proposed Method

We propose a novel prior – dark channel prior - for single image haze removal. The dark channel prior is based on the statistics of outdoor haze-free images. We find that, in most of the local regions which do not cover the sky, it is very often that some pixels (called dark pixels) have very low intensity in at least one colour (RGB) channel. In hazy images, the intensity of these dark pixels in that channel is mainly contributed by the air light. Therefore, these dark pixels can directly provide an accurate estimation of the haze transmission. To improve the quality of the resulting transmission map, we develop a soft matting interpolation method. Various experiments show that we can recover a high-quality haze-free image and produce a good depth map. Our approach is physically valid and is able to handle distant objects in heavily hazy images. We do not rely on significant variance of transmission or surface shading. The result contains few artifacts.

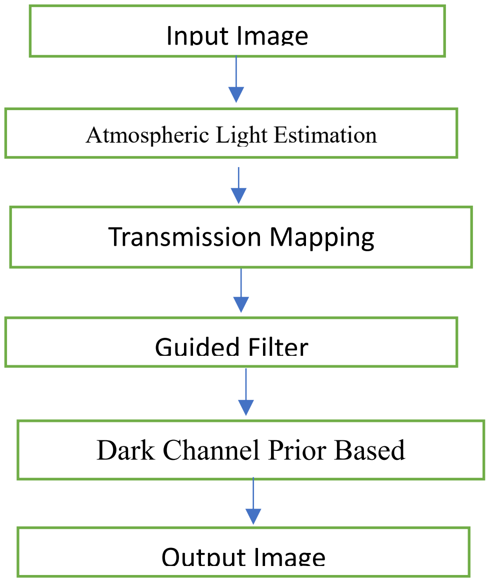


Fig 4.1 Block Diagram Dark Channel Prior

A prior is the assumption or knowledge that can be built beforehand. Tan's method is based on the prior that the scene radiance J should have a better visibility than the hazy image I. Fattal's method is based on the prior that the object luminance l and the transmission t are statistically independent. We find that both priors talk about the interaction between the scene radiance (J or l) and the haze (I or t). But let us consider an image taken in a clear day in which no haze exists. Human beings are able to tell whether it is a haze-free image, even there is no interaction between the scene radiance and the haze at all. This motivates us to find a prior, which concerns the scene radiance J (an haze-free image) alone. We propose the dark channel prior which is solely about haze-free image. In the following, we first propose our observation and give intuitive explanation. Then we introduce the dark channel prior in a mathematical form. We further design experiments to verify this prior.

4.1Observation

Our observation in outdoor haze-free images reveals a notable phenomenon: within regions of the image devoid of sky coverage, there exist pixels exhibiting extremely low intensity, bordering on zero, in at least one of the color channels. These pixels, termed "dark pixels", warrant a closer examination of the contributing factors. Primarily, shadows emerge as a significant contributor. The outdoor environment abounds with intricate interplays of light and shadow, with objects such as trees, buildings, and vehicles casting distinct shadows. Objects characterized by irregular geometries, such as rocks and foliage, readily lend themselves to casting shadows. Moreover, urban landscapes often present instances where the external surfaces of buildings appear dark owing to the stark contrast between indoor illumination and the ambient outdoor light, effectively creating shadows. Furthermore, the presence of dark pixels can be attributed to the characteristics of colourful objects. Objects with low reflectance across any colour channel inherently contribute to the manifestation of dark pixels. This phenomenon underscores the intricacies of light interaction and color perception within the image domain, exemplifying the nuanced interplay between object properties and illumination conditions.

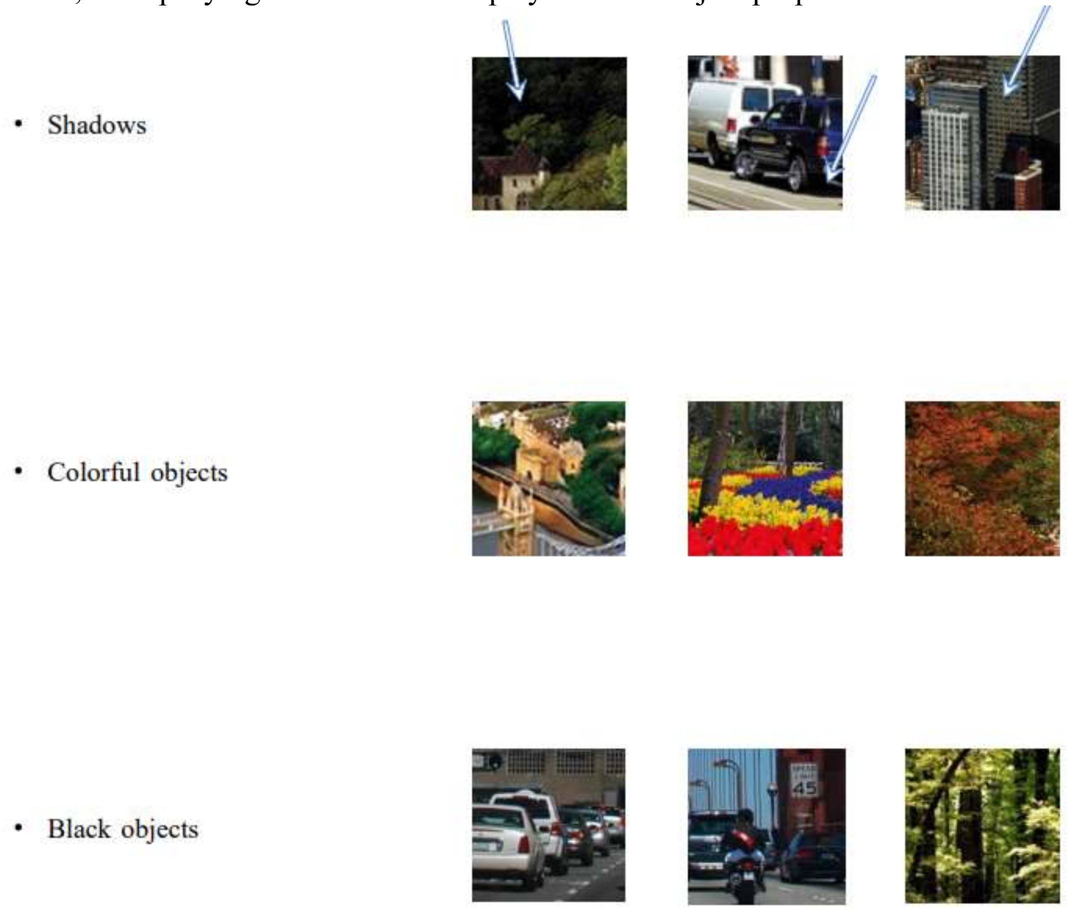


Fig 4.2 Factors Contributing to Dark Pixels

Shadows, colourful objects, and black items all contribute to dark pixels in images. For example, green appears dark in its red and blue channels, while yellow appears dark in its blue channel. Outdoor scenes feature various colored objects like flowers, cars, and pedestrians, resulting in many dark pixels. A pixel is considered dark if it has low intensity in at least one color channel. Additionally, black objects like tires and road signs also produce dark pixels. These factors contribute to the presence of dark pixels in image patches.

Atmospheric Light Estimation:

We need to estimate the atmospheric light in our method, but it's not straightforward. Traditionally, people assume the colour of the haziest regions as the atmospheric light, but finding these regions is tricky because haze estimation comes after atmospheric light estimation. Some methods ask users to mark these regions, but in most cases, we need automatic methods.

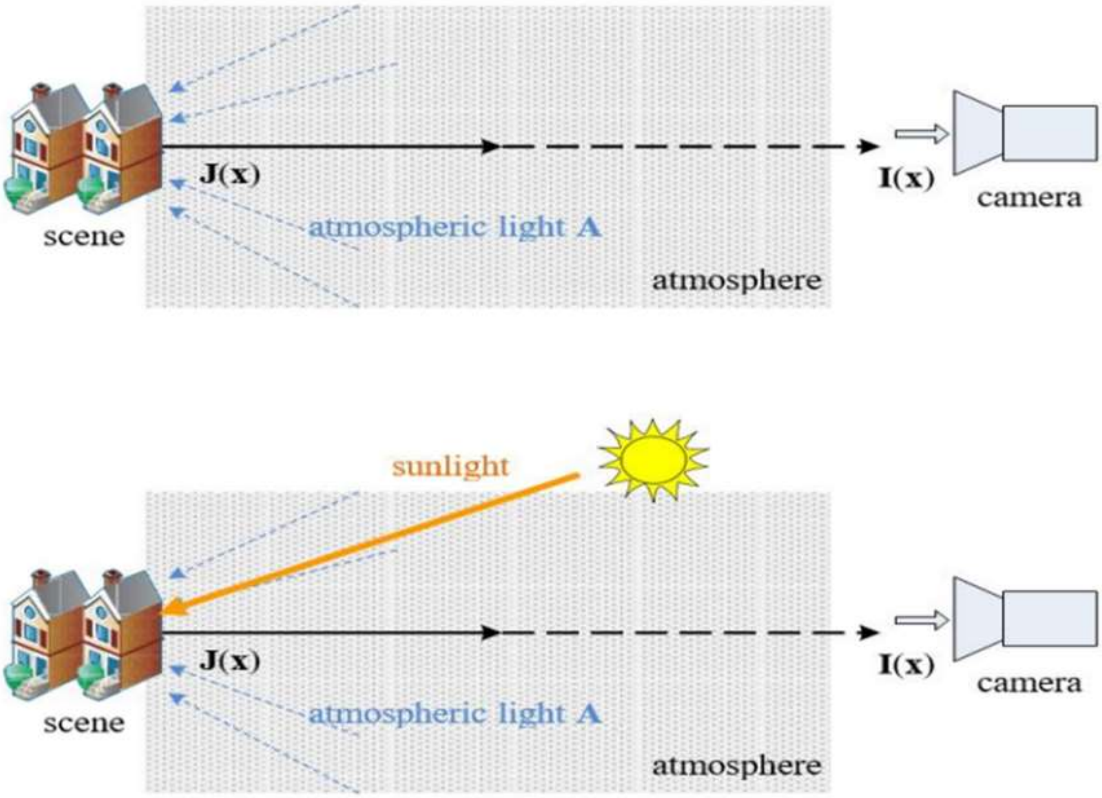


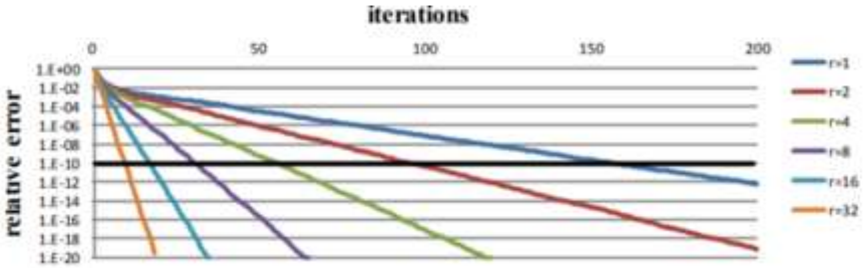
Fig 4.4 Atmospheric Light Estimation

On hazy days, there are typically two main sources of illumination to consider: the atmospheric light (Ac) and sunlight or light from clouds (S). In ideal conditions where the atmospheric light is the sole source, the brightest intensity of each colour channel in the image is closest to Ac.

Guided Image Filtering

We go back to the motivation of the soft matting: we expect to combine the pixelwise constraints with spatial continuity concerns. Inspecting , we find that the refined transmission t has intensity like t ˜, but has consistent edges with I. It appears that the map t ˜ undergoes a fi process and becomes t, and the process appears to be "aware" of the edges in the image I. The solution to the soft matting can be written as:

$$t = \lambda(L + \lambda U)^{-1}\tilde{t}.$$



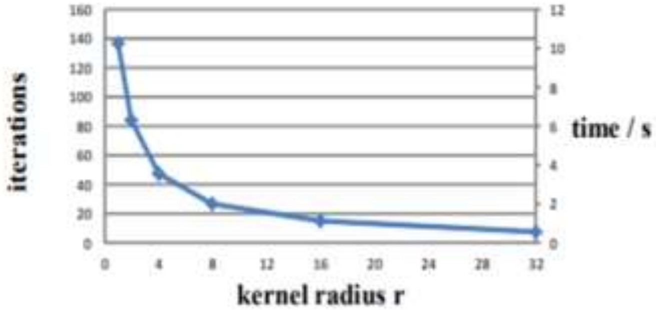


Fig.4.5 Convergence vs Kernel Radius

The iteration numbers correspond to the error 1e−10 This is actually a translation-variant filtering process:

$$t_i = \sum_j W_{ij}\bar{t}_j,$$

The text introduces the guided filter, a method for edge-aware filtering. Unlike traditional approaches that require solving linear systems for filtering kernels, the guided filter directly computes weights based on the input image. This ensures consistency between the filtered output and the original image, particularly emphasizing edges. By explicitly defining weights, the need for solving linear systems is eliminated, streamlining the filtering process. Additionally, a fast O(N) algorithm is introduced, enabling real-time performance regardless of kernel size. Edge-aware filtering is crucial in computer vision and graphics, and the guided filter offers advantages in speed and quality over existing techniques. Various applications are demonstrated, including haze removal.

5.Results and Conclusion

The algorithm successfully improves the visual quality and clarity of input images through dehazing and enhancement techniques. Dark Channel Prior: Identifies haze-free regions and estimates haze thickness, crucial for subsequent steps. Atmospheric Light Estimation: Accurately estimates atmospheric light, aiding in scene colour restoration and detail recovery.

Transmission Map Estimation: Computes haze extent per pixel, facilitating haze attenuation and scene restoration. Transmission Refinement: Improves transmission map accuracy, smoothing out artifacts and preserving edge details. Image Reconstruction: Unveils scene details obscured by haze, significantly enhancing visual quality. MSRCR Enhancement: Optionally enhances contrast and color, adding refinement for a visually appealing output.

Performance Evaluation: Metrics like PSNR, SSI, and NRMSE assess image quality, showing fidelity to the original input. Overall, the algorithm effectively dehazes and enhances underwater and low-light images, improving visibility and clarity in challenging conditions.


(a) (b) (c) (d)

Fig.5.1 Output 1

(a) Original image (b)MSRCR+Guided Filter (c) Dark channel Implementation (d) Enhanced Image

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PSNR: 5.607656987022106
SSI: 0.003102837675007251
NRMSE: 0.5548049005490614
Computational Time: 0.21881103515625 seconds
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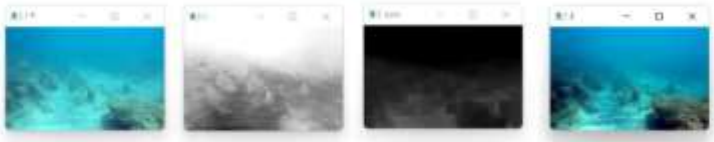


(a) (b) (c) (d)

Fig.5.2 Output 2

(a) Original image (b)MSRCR+Guided Filter (c) Dark channel Implementation (d) Enhanced Image

PSNR: 4.870306223409442

SSI: 0.008589914644890685

NRMSE: 0.5798973815889208

Computational Time: 0.1880807876586914 seconds

(a) (b) (c) (d)

Fig.5.3 Output 3

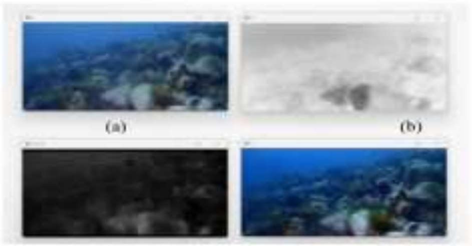
(a) Original image (b)MSRCR+Guided Filter (c) Dark channel Implementation (d) Enhanced Image

PSNR: 7.692887294073257

SSI: 0.009897428413411695

NRMSE: 0.4914530587133541

Computational Time: 0.26552367210388184 seconds



(a) (b) (c) (d)

Fig.5.4 Output 4

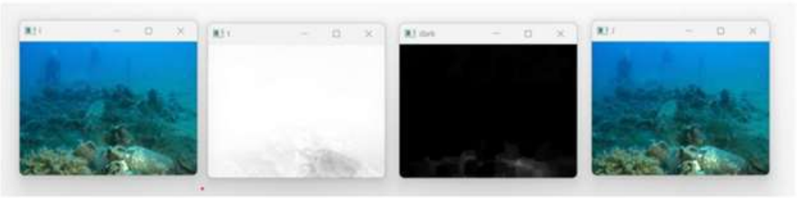
(a) Original image (b)MSRCR+Guided Filter (c) Dark channel Implementation (d) Enhanced Image

PSNR: 8.520747109873204

SSI: 0.004963961347992609

NRMSE: 0.40341726333465144

Computational Time: 0,9377832412719727 seconds



(a) (b) (c) (d)

Fig.5.4 Output 4

(a) Original image (b)MSRCR+Guided Filter (c) Dark channel Implementation (d) Enhanced Image5

PSNR: 7.185089705138782

SSI: 0.04191064922903313

NRMSE: 0.43726580369846035

Computational Time: 0.2660830020904541 seconds

Conclusion

In conclusion, the dehazing and enhancement algorithm demonstrates remarkable and low-light conditions. By meticulously estimating atmospheric light and computing transmission maps, followed by refined adjustments using guided filters, the algorithm adeptly eliminates haze and elevates image quality. Furthermore, the optional inclusion of MSRCR enhancement offers an additional layer of refinement, enhancing contrast and color fidelity to create aesthetically pleasing outputs. The validation of high-performance metrics corroborates the accuracy and fidelity of the reconstruction process. With far-reaching applications across domains such as marine biology, oceanography, surveillance, and remote sensing, this algorithm emerges as a pivotal tool for achieving clearer imaging amidst challenging environmental circumstances.

5.2 Future Scope

The algorithm offers exciting opportunities for future improvements. One idea is to explore advanced machine learning methods to make haze removal and image enhancement even better. By training deep learning models with a wide range of underwater and low-light images, we can teach them to recognize complex patterns and improve the way they remove haze. We could also work on making the algorithm faster so it can be used in real-time applications like underwater robots and self-driving cars. Another area to explore is how well the algorithm works in different environments and if it can handle different types of haze. By testing it with various conditions, we can make sure it's reliable. We could also try integrating it with underwater cameras and sensors to use it for tasks like exploring underwater areas and monitoring them. Overall, there's a lot of potential to make imaging technology better, especially in challenging environments.

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