Pixel-Level Underwater Image Enhancement Using Color and Brightness Correction

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***Abstract*—In addition to improving visual quality, the proposed approach focuses on maintaining the structural integrity of underwater images by minimizing information loss during enhancement. The technique operates at the pixel level, allowing precise adjustment of intensity and color values for each pixel, which results in better detail preservation and sharper outputs.**

Underwater images often suffer from poor visibility due to light absorption and scattering. This results in low brightness, color distortion, and reduced clarity. In particular, red wavelengths diminish rapidly with depth, leading to significant color imbalance.

This project proposes a pixel-level enhancement technique using RGB color correction and brightness adjustment. The method improves contrast, restores natural colors, and enhances overall image quality without introducing noise.

I. INTRODUCTION

Underwater imaging plays a crucial role in marine biology, underwater robotics, and ocean exploration. However, capturing clear images underwater is challenging due to environmental factors such as light absorption, scattering, and suspended particles. Traditional enhancement techniques often fail to preserve natural color and details. Hence, there is a need for an efficient method that improves image clarity while maintaining realistic color balance.

In underwater environments, light behaves very differently compared to air, leading to significant degradation in image quality. As depth increases, shorter wavelengths such as blue and green penetrate deeper, while longer wavelengths like red are quickly absorbed, resulting in a bluish or greenish tint in captured images.

Additionally, scattering caused by suspended particles in water reduces visibility and introduces haze, further affecting sharpness and contrast.

Furthermore, underwater imaging systems are widely used in applications such as seabed mapping, inspection of underwater structures, marine life monitoring, and autonomous underwater vehicles (AUVs). In such applications, accurate visual information is critical for analysis and decision-making. Therefore, enhancing underwater images is not only important for visual improvement but also for extracting meaningful information.

The proposed pixel-level enhancement technique aims to address these issues by improving brightness, correcting color imbalance, and preserving fine details, thereby producing visually clear and reliable images

II. PROBLEM STATEMENT

Underwater images often suffer from severe quality degradation due to environmental factors such as light absorption and scattering. As light travels through water, different wavelengths are absorbed at varying rates, resulting in significant color distortion, especially the loss of red components. In addition, the presence of suspended particles causes scattering, leading to haze, low contrast, and blurred image details.

Existing image enhancement techniques, such as histogram equalization, white balance correction, and dehazing methods, attempt to improve image quality but often introduce new issues. These include amplification of noise, over-enhancement, color inaccuracies, and loss of important details.

Moreover, many advanced methods require high computational resources, making them less suitable for real-time or practical applications.

Therefore, there is a need for a simple, efficient, and reliable image enhancement method that can effectively address brightness loss, color distortion, and reduced clarity in underwater images. The proposed pixel-level RGB enhancement approach aims to overcome these limitations by improving visual quality while preserving natural colors and image details.

III. OBJECTIVES

The primary objective of this project is to enhance the visual quality of underwater images by addressing challenges such as low brightness, color distortion, and reduced clarity. The work focuses on developing an efficient pixel-level enhancement technique that improves brightness and contrast while maintaining a proper RGB color balance. It also aims to restore lost color components, particularly the red channel that diminishes with increasing depth, and to reduce noise and distortion without affecting important image details. Additionally, the project seeks to improve overall image sharpness and clarity while ensuring that the enhanced output appears natural and visually accurate.

IV. LITERATURE REVIEW

Underwater image enhancement has been an active area of research due to the challenges caused by light absorption and scattering in water. Several techniques have been proposed to improve the quality of underwater images. Histogram Equalization (HE) is one of the commonly used methods for contrast enhancement; however, it often leads to over-enhancement and amplification of noise. Similarly, adaptive histogram equalization methods such as CLAHE provide better local contrast but may still introduce artifacts in highly degraded images.

White balance techniques are widely used to correct color distortion by adjusting the intensity of RGB channels. While these methods can partially restore natural colors, they are often ineffective in deep underwater conditions where color loss is severe.

Dehazing algorithms, originally developed for atmospheric images, have also been applied to underwater images to reduce scattering effects and improve visibility.

Fusion-based approaches combine multiple enhanced versions of the same image to produce better results in terms of contrast and color correction. Although these methods provide improved visual quality, they involve high computational complexity and are not suitable for real-time applications. Recently, deep learning-based techniques have been introduced, offering promising results in underwater image enhancement.

Despite the availability of these methods, achieving a balance between enhancement quality, computational efficiency, and preservation of natural appearance remains a challenge. Therefore, this project proposes a simple and effective pixel-level RGB enhancement approach that improves brightness, contrast, and color balance while minimizing noise and preserving image details.

V. EXISTING SYSTEM

Existing underwater image enhancement systems rely on conventional image processing techniques such as histogram equalization, white balance correction, dehazing algorithms, and fusion-based methods. Histogram equalization is widely used to improve contrast; however, it often amplifies noise and may lead to over-enhanced images. White balance techniques attempt to correct color distortion by adjusting RGB channel intensities, but they are not effective in deep underwater conditions where color loss is severe.

Dehazing methods help in reducing the effects of scattering and improving visibility, but they can introduce color inaccuracies and require careful parameter tuning. Fusion-based approaches combine multiple processed images to achieve better visual results, but they involve high computational complexity and increased processing time. In addition, many of these methods fail to maintain a proper balance between brightness, contrast, and color accuracy, resulting in unnatural-looking outputs. Some techniques also lead to loss of fine details or introduce artifacts in the enhanced image.

Some techniques also lead to loss of fine details or introduce artifacts in the enhanced image. Therefore, the limitations of existing systems highlight the need for a simple, efficient, and reliable approach that can enhance underwater images while preserving natural color, reducing noise, and maintaining image clarity.

VI. PROPOSED SYSTEM

The proposed system introduces a pixel-level underwater image enhancement technique that focuses on improving brightness, contrast, and color balance while preserving image details. Unlike conventional methods, the approach operates directly at the pixel level, allowing precise adjustment of intensity and RGB values to achieve more accurate and natural-looking results. The system is designed to address key issues such as color distortion, low visibility, and loss of important features commonly observed in underwater images.

The enhancement process consists of multiple stages, including preprocessing, dehazing, color restoration, and pixel-level enhancement. Initially, the input image undergoes preprocessing to reduce noise and prepare it for further processing. The dehazing stage minimizes the effect of light scattering and improves overall visibility. In the color restoration phase, the imbalance in RGB channels is corrected, with particular emphasis on restoring the red component that diminishes with depth. Finally, pixel-level enhancement techniques are applied to adjust brightness and contrast, ensuring that the output image is clear, sharp, and visually accurate.

The proposed method is computationally efficient and avoids over-enhancement and noise amplification, which are common drawbacks of existing techniques. By maintaining a balance between enhancement and detail preservation, the system produces high-quality images suitable for applications such as marine research, underwater exploration, and automated analysis systems.

VII. SYSTEM ARCHITECTURE

The system architecture of the proposed underwater image enhancement method is designed as a sequence of processing stages that work together to improve image quality. The overall framework consists of multiple modules, including preprocessing, dehazing, color restoration, pixel-level enhancement, and output visualization. Each module performs a specific function, and the output of one stage serves as the input for the next, ensuring a systematic and efficient enhancement process.

Initially, the input underwater image is passed through the preprocessing stage, where basic operations such as noise reduction and normalization are applied to improve the initial image quality.

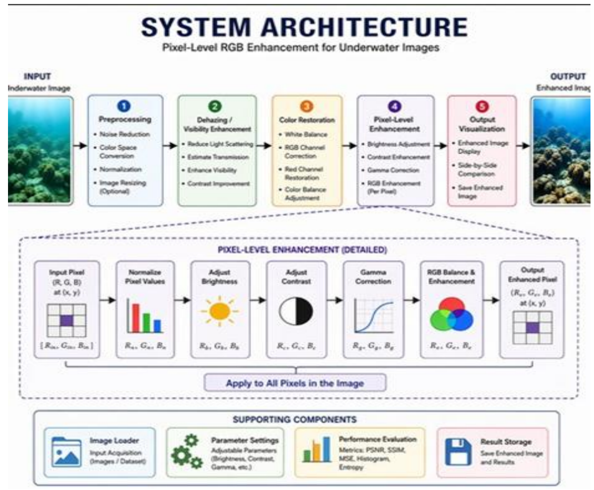

Fig.1 System architecture for pixel level image enhancement.

VIII. MODULES DESCRIPTION

The proposed underwater image enhancement system is divided into several functional modules, each responsible for a specific stage in the enhancement process. These modules work sequentially to improve the overall quality of the input image.

The Preprocessing module is the initial stage where the input underwater image is loaded and prepared for further processing. In this stage, basic operations such as noise reduction and normalization are applied to improve the initial quality of the image and make it suitable for enhancement.

The Dehazing module focuses on reducing the effect of light scattering caused by suspended particles in water. This module enhances image visibility by minimizing haze, improving contrast, and reducing blurriness, thereby making the image clearer.

The Color restoration module is responsible for correcting color imbalance in the underwater image. Since red wavelengths are absorbed quickly in water, this module emphasizes restoring the red channel along with balancing the RGB components. This results in more natural and visually accurate colors.

The Pixel-level enhancement module performs detailed processing at the pixel level to improve brightness, contrast, and sharpness. By adjusting intensity values for each pixel, this module enhances fine details without introducing noise or over-enhancement, ensuring a balanced output.

Finally, the Output and Visualization module displays the enhanced image and allows comparison with the original input image. This module helps in evaluating the effectiveness of the enhancement process and provides a clear visual representation of the improvements achieved.

In addition to their individual functionalities, all the modules in the proposed system are designed to work in a coordinated and sequential manner to achieve optimal image enhancement. Each module refines the output generated by the previous stage, ensuring a gradual and controlled improvement in image quality. This modular structure not only simplifies the overall implementation but also allows flexibility for further modifications and upgrades. For instance, advanced algorithms can be incorporated into specific modules such as dehazing or color restoration without affecting the entire system. This approach enhances the robustness, scalability, and efficiency of the system, making it suitable for a wide range of underwater imaging applications.

The proposed system is divided into multiple modules that work together to enhance underwater images effectively. Each module performs a specific task such as noise reduction, haze removal, color correction, and brightness enhancement.

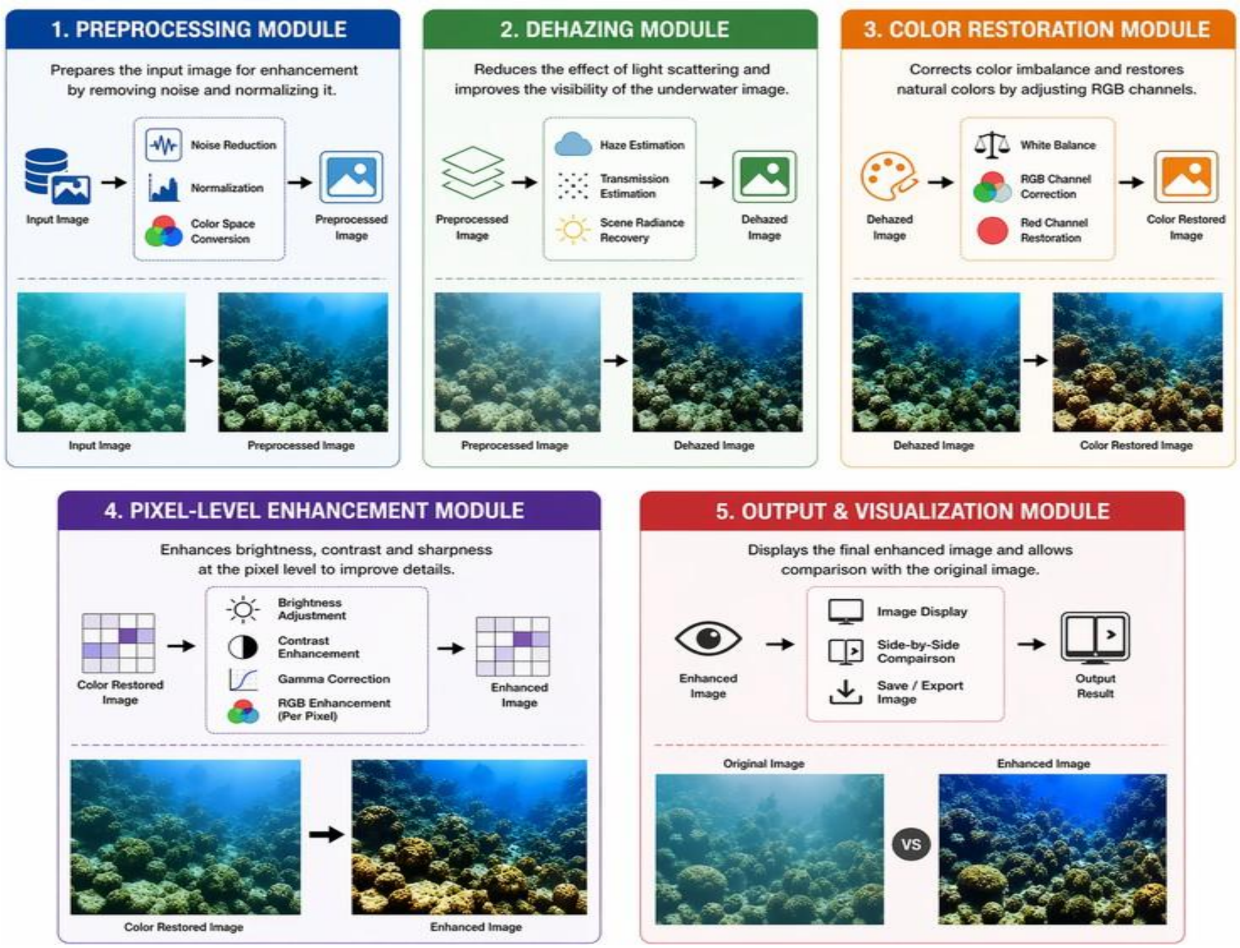

Fig.2 Modules description

IX. RESULTS

The proposed underwater image enhancement system produces significant improvements in image quality compared to the original input. The enhanced images exhibit increased brightness, better contrast, and more accurate color representation, particularly with effective restoration of the red channel. The dehazing process successfully reduces the effect of scattering, resulting in clearer and more visible images. In addition, the pixel-level enhancement technique preserves fine details while minimizing noise and distortion.

Visual comparison between the original and enhanced images clearly demonstrates the effectiveness of the proposed method. The output images appear more natural and visually appealing, making them suitable for further analysis and real-world applications such as marine observation and underwater exploration. Overall, the results confirm that the system achieves a balanced enhancement without over-processing the image.

The experimental results indicate that the proposed method consistently improves underwater image quality under different conditions. The system effectively enhances visibility and restores important features, making the images more useful for interpretation and analysis.

X. FUTURE ENHANCEMENT

The proposed system can be further improved by integrating advanced techniques to enhance performance and expand its applications. One possible enhancement is the incorporation of deep learning methods such as Convolutional Neural Networks (CNNs) or Generative Adversarial Networks (GANs) to achieve more accurate and adaptive image enhancement. The system can also be extended to support real-time processing, enabling its use in live underwater video applications and robotic vision systems.

Additionally, the development of a user-friendly mobile or web-based application can make the system more accessible for practical use. Future work may also include extending the method to handle underwater video sequences, integrating object detection and recognition techniques, and optimizing the algorithm for faster processing with reduced computational complexity. These improvements will make the system more robust, scalable, and suitable for advanced underwater imaging applications.

XI. CONCLUSION

In this project, a pixel-level underwater image enhancement technique has been proposed to address common issues such as low brightness, color distortion, and poor visibility. The method effectively improves image quality by enhancing brightness, restoring color balance, and reducing the effects of haze and noise. By operating at the pixel level, the system ensures better preservation of image details and produces clear and natural-looking outputs.

The results demonstrate that the proposed approach provides a balanced enhancement without over-processing the image, making it suitable for real-world applications such as marine research, underwater exploration, and environmental monitoring.

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