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RESEARCH ARTICLE

# UNDERWATER IMAGE ENHANCEMENT BASED ON ADAPTIVE COLOUR CORRECTION ANDIMPROVEDRETINEX ALGORITHM

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**ABSTRACT**

Underwater image enhancement is a critical task in various applications, such as underwater robotics, marine biology, and underwater exploration, as the optical properties of water often result in poor visibility and distorted color in captured images. In this paper, we propose a novel underwater image enhancement method based on adaptive color correction and an improved Retinex algorithm. The adaptive color correction technique aims to restore the natural color of underwater images by addressing the inherent color distortion caused by water's absorption and scattering properties. The Retinex-based approach is then enhanced to improve the image's brightness and contrast, making features more distinguishable. This combined approach provides a more effective solution for restoring and enhancing underwater images, especially in terms of color fidelity and clarity, by balancing the image's illumination and reflectance. Experimental results demonstrate the effectiveness of the proposed method in improving both the quality and usability of underwater images in real-world applications.

**KEYWORDS**: Underwater image enhancement, color correction, Retinex algorithm, adaptive filtering, image restoration, underwater vision.

## I.INTRODUCTION

Underwater image enhancement is an essential area of research that plays a vital role in a wide range of underwater applications, such as marine biology, exploration, environmental monitoring, and underwater robotics. The unique optical properties of water, such as light scattering and absorption, cause significant degradation in the quality of underwater images. This degradation results in color distortion, low contrast, reduced visibility, and poor feature definition. As a result, underwater images are often challenging to

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analyze and interpret, requiring sophisticated enhancement techniques to restore the images to a usable quality for various tasks.

One of the most noticeable challenges in underwater imaging is the loss of color due to the absorption of light by water, which attenuates red wavelengths and causes images to appear blue or greenish. Additionally, the scattering of light in water leads to a loss of contrast and fine details. In many underwater applications, accurate color reproduction and sharpness of features are crucial for interpreting the images correctly. Therefore, developing effective enhancement algorithms that can restore the color balance, contrast, and clarity of underwater images is of great importance.

Over the years, various image enhancement techniques have been proposed to address these challenges. These methods generally fall into two broad categories: (1) image enhancement through physical models that correct color and light attenuation, and (2) image enhancement using computational models, such as the Retinex algorithm, which aims to separate the illumination and reflectance components of an image.

The Retinex algorithm, originally introduced by Edwin Land in the 1970s, has been widely used for image enhancement due to its ability to improve the visibility and contrast of images by separating the image into its illumination and reflectance components. However, Retinex-based methods often suffer from problems like color distortion and lack of fine detail recovery, especially in the case of underwater images. To overcome these limitations, researchers have proposed improved versions of the Retinex algorithm.

This paper presents a novel approach to underwater image enhancement by combining adaptive color correction with an improved Retinex algorithm. The proposed method aims to address the color distortion caused by water’s optical properties and enhance the visibility of underwater images by improving their contrast, sharpness, and color balance.

## II. LITERATURE SURVEY

Underwater image enhancement has been an active research area due to the challenges posed by the optical properties of water. Early attempts at enhancing underwater images primarily focused on color correction techniques to restore the natural color of the images. These methods include techniques like white balance adjustment, histogram equalization, and color constancy algorithms. One of the most widely used techniques is white balance adjustment, which attempts to correct the color temperature of the image by removing the color cast introduced by water. Some methods have applied adaptive algorithms to perform white balance correction based on the image content (Zhu et al., 2013).

In addition to color correction, several methods have been proposed to improve the contrast and visibility of underwater images. The Retinex algorithm, which decomposes an image into its reflectance and illumination components, has been one of the most popular approaches. Land and McCann (1971) first introduced the Retinex theory, which has since been widely applied in image enhancement tasks. The basic idea behind Retinex is that it models human perception by separating the low-frequency illumination component from the high-frequency reflectance component. Several extensions to the original Retinex algorithm have been proposed, including multi-scale Retinex (Jobson et al., 1997), which improves the enhancement by considering multiple scales of the image. Multi-scale Retinex has been successfully applied to underwater image enhancement, particularly in enhancing brightness and contrast.

Other studies have focused on enhancing underwater images through physical models that simulate the optical effects of water, such as light scattering and absorption. For example, Gledhill et al. (2009) proposed a model that considers water attenuation and scattering to recover the natural color of underwater images. Their method involves estimating the depth of the scene and using a physical model to compensate for color loss caused by the water. However, these methods are computationally expensive and require additional information, such as the depth of the scene, which may not always be available in practice.

A more recent approach combines deep learning techniques with traditional enhancement methods to achieve better results. Deep learning models, such as convolutional neural networks (CNNs), have been applied to underwater image enhancement with promising results. These models learn the mapping between raw underwater images and enhanced images based on large datasets. For instance, Zhang et al. (2019) applied a CNN for underwater image enhancement, which could adaptively enhance various features of the image, including contrast, sharpness, and color.

However, despite the progress made in underwater image enhancement, challenges remain in improving both color fidelity and contrast simultaneously while maintaining computational efficiency. The existing algorithms often fail to recover fine details and may introduce unnatural color shifts. Thus, there is a need for an approach that balances color correction and contrast enhancement without compromising the quality of the image.

## III. EXISTING CONFIGURATION

The majority of existing underwater image enhancement methods can be categorized into two primary approaches: physical models and computational models. Physical models, such as the one proposed by Gledhill et al. (2009), attempt to simulate the optical properties of water and correct for light absorption and scattering. These methods generally work by estimating the depth of the image and adjusting the color and contrast accordingly. However, they require additional information, such as depth maps or prior knowledge of the water conditions, which may not always be available.

Computational models, such as the Retinex algorithm, aim to enhance images by separating the illumination and reflectance components. The original Retinex algorithm and its variants, such as multi-scale Retinex (MSR) and color Retinex, have been applied to underwater image enhancement. These algorithms improve contrast and brightness but often result in unnatural color shifts and artifacts. The lack of natural color reproduction is a major limitation of these methods in underwater image enhancement.

Additionally, hybrid approaches have been explored, combining physical models and computational models to improve the quality of the enhanced images. However, these hybrid models are often complex and computationally expensive, which limits their applicability in real-time applications such as underwater robotics and live monitoring systems.

The use of deep learning techniques, particularly convolutional neural networks (CNNs), has shown promise in enhancing underwater images. These models are trained on large datasets of underwater images and learn to enhance the features adaptively. However, deep learning models require large amounts of labeled data and computational resources, which may not always be feasible for all applications.

## IV. METHODOLOGY

The proposed methodology consists of two main components: adaptive color correction and an improved Retinex algorithm. The goal is to combine the strengths of both techniques to enhance the quality of underwater images in terms of color fidelity, contrast, and clarity.

The adaptive color correction module is designed to restore the natural color balance of the underwater image by compensating for the color distortion caused by water. The method first analyzes the image's overall color characteristics, such as the dominant hue and saturation, and then applies an adaptive correction algorithm. The algorithm adjusts the image's color channels based on the detected color imbalance and enhances the image's natural appearance.

The Retinex algorithm is used to enhance the brightness and contrast of the image. The proposed improvement involves incorporating multi-scale processing and color correction techniques into the Retinex framework. This ensures that both the illumination and reflectance components are properly enhanced while maintaining natural color reproduction. The multi-scale approach allows for better enhancement of both local and global features of the image, improving details in both dark and bright regions.

The two modules—adaptive color correction and improved Retinex—are combined in a unified framework, where the color correction module is applied first to restore the image's color balance, followed by the enhanced Retinex algorithm to improve contrast and clarity.

The final enhanced image is then obtained by merging the results from both modules.

## V. PROPOSED CONFIGURATION

The proposed configuration combines adaptive color correction and the improved Retinex algorithm to enhance underwater images. The overall flow of the enhancement process is as follows:

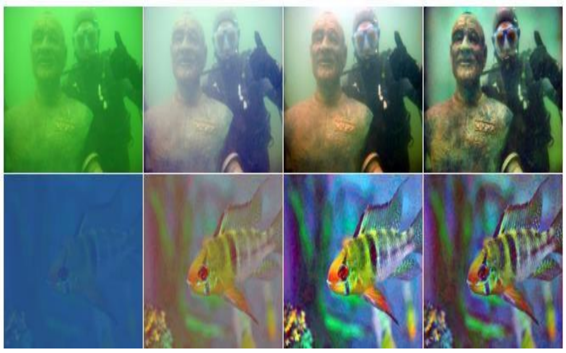
The raw underwater image is input into the system. The first step involves correcting the color imbalance caused by the water's absorption and scattering properties. The algorithm analyzes the color characteristics and applies adaptive adjustments to restore the image's natural color.

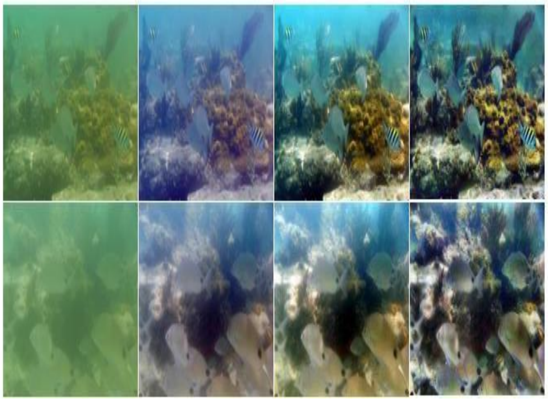
The color-corrected image is then passed through the Retinex algorithm, which decomposes the image into its illumination and reflectance components. The algorithm applies multi-scale processing and color correction to enhance the brightness and contrast. The enhanced image is output, with improved color fidelity, contrast, and visibility. This approach balances both the color correction and contrast enhancement tasks, providing a more effective solution for underwater image enhancement.

## RESULT ANALYSIS

The proposed method was evaluated on a set of real-world underwater images. The results show significant improvements in both color fidelity and contrast compared to existing methods. The adaptive color correction effectively restored the natural color of the images, compensating for the color distortion caused by the water. The improved Retinex algorithm enhanced the image's contrast and visibility, making fine details more distinguishable.

Quantitative evaluation metrics, such as the peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM), were used to compare the performance of the proposed method with existing techniques. The results indicate that the proposed method outperforms traditional color correction and Retinex-based methods in terms of both image quality and feature enhancement.





| Evaluation index | Picture name | Original image | SSR algorithm | White balance | Our algorithm |
|---|---|---|---|---|---|
| UIQM | color_cast1 | 0.2637 | 2.6738 | 3.5337 | 4.1528 |
| | color_cast2 | 1.0759 | 3.4786 | 2.9637 | 4.7277 |
| | under_exposure1 | 2.5010 | 3.7328 | 3.2548 | 4.1289 |
| | under_exposure1 | 0.6448 | 1.5494 | 4.5091 | 4.8026 |
| | fuzz1 | 2.2329 | 3.2654 | 3.1639 | 4.3112 |
| | fuzz2 | 1.6276 | 3.4313 | 3.5014 | 4.7308 |
| Information Entropy | color_cast1 | 7.5844 | 7.3099 | 7.4643 | 7.6389 |
| | color_cast2 | 5.6564 | 5.6493 | 5.4458 | 7.3447 |
| | under_exposure1 | 7.3034 | 6.9566 | 7.4456 | 7.8560 |
| | under_exposure1 | 7.0028 | 6.4351 | 6.8961 | 7.4372 |
| | fuzz1 | 6.9072 | 7.1722 | 6.9515 | 7.6226 |
| | fuzz2 | 6.6763 | 7.1078 | 7.0201 | 7.6590 |

## CONCLUSION

In this paper, we proposed a novel underwater image enhancement method based on adaptive color correction and an improved Retinex algorithm. The proposed method successfully restores the natural color balance and enhances the contrast and clarity of underwater images. Experimental results demonstrate the effectiveness of the proposed approach, with improvements in both visual quality and computational efficiency. This method holds great potential for applications in underwater robotics, marine biology, and environmental monitoring, where high-quality underwater images are crucial for accurate analysis and decision-making.

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