**Underwater Dehazing**

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***Abstract - Capturing clear underwater images remains a challenge, with light attenuation and scattering obscuring details and distorting colors. Existing dehazing methods frequently tackle color correction and dehazing separately, leading to unnatural color balance. They often rely on simplified, unrealistic attenuation models and struggle to preserve image details during dehazing. Jointly addressing color correction and dehazing ensures consistent color balance throughout the process, resulting in more natural and realistic images. We move beyond simplified models by estimating the spatially-varying attenuation for each color channel using a data-driven approach, leading to more accurate color restoration in diverse underwater environments. Through advanced filtering techniques, we selectively remove haze while safeguarding fine details within the image, ensuring enhanced images remain informative and suitable for further analysis. This combined approach empowers our algorithm to achieve demonstrably superior performance in dehazing underwater images. By effectively removing haze, maintaining natural color balance, and preserving details, we aim to deliver significantly clearer and more informative images compared to existing methods. Our research holds significant promise for advancing underwater image processing and facilitating various applications, including improved visual guidance for robotic systems, enhanced accuracy in object detection and recognition tasks, and detailed monitoring of underwater environments and ecosystems. This ultimately enables unlocking the full potential of underwater images for scientific discovery and technological advancement.***

**I. Introduction**

The vast underwater world holds immense potential for scientific exploration, resource discovery, and environmental monitoring. However, capturing clear and informative images underwater poses significant challenges due to light attenuation and scattering, resulting in color casts and haze effects. These factors severely degrade image quality, hindering the performance of vision-based tasks crucial for autonomous underwater vehicles (AUVs), robots, and scientific analysis.

Existing underwater dehazing methods often fall short in addressing these issues effectively. Many approaches perform color correction and dehazing separately, leading to unnatural color balance in the final image. Other methods rely on oversimplified attenuation models that fail to capture the complex underwater light dynamics. Consequently, these methods struggle to preserve details while achieving accurate color restoration.

This paper proposes a novel dehazing algorithm, specifically designed to tackle these challenges and achieve improved underwater image enhancement. Our algorithm incorporates key innovations to provide several advantages:

**1. Joint Color Correction and Dehazing:** Instead of treating these processes separately, we integrate them into a unified framework. This ensures consistent color balance throughout the dehazing process, leading to more natural and realistic results.

**2. Adaptive Attenuation Modeling:** We move beyond simplified models by employing a data-driven approach to estimate the spatially-varying attenuation for each color channel. This enables our algorithm to accurately handle diverse underwater environments and achieve better fidelity in color restoration.

**3. Detail-Preserving Dehazing:** We leverage advanced filtering techniques to selectively remove haze while preserving fine details within the image. This ensures that enhanced images remain visually informative and suitable for further analysis or visual inspection.

**4. Enhanced Clarity and Visibility:** By combining these innovations, our [Name of Your Algorithm] algorithm aims to achieve superior performance in dehazing underwater images. By removing haze effectively while maintaining natural color balance and preserving details, we strive to deliver significantly clearer and more informative images compared to existing methods.

This paper will evaluate the performance of our algorithm on various underwater image datasets, demonstrating its effectiveness in enhancing clarity, restoring natural colors, and preserving details. We will compare our results with state-of-the-art methods to highlight the advantages and potential impact of our algorithm.

This research holds significant promise for advancing underwater image processing and facilitating various applications, including:

* Improved visual guidance for AUVs and robots
* Enhanced accuracy in object detection and recognition tasks
* Detailed monitoring of underwater environments and ecosystems
* More precise analysis of biologica1. l and geological features

By overcoming the limitations of existing methods, our algorithm represents a significant step towards unlocking the full potential of underwater images for scientific discovery and technological advancement.

**II. Literature Review**

In paper [1] the proposed method for underwater image dehazing employs a two-step approach to address colour distortion and low contrast caused by light absorption and scattering. Firstly, a novel colour correction technique compensates for selective absorption, considering wavelength-dependent absorption in natural water. Secondly, a dual transmission map-based haze removal technique is applied, utilizing a novel colour channel with two terms to accurately estimate the transmission maps. Experimental results demonstrate that the proposed method outperforms existing techniques, showing significant improvement in patch-based contrast quality index (PCQI) and Entropy metrics, with an 8.6% and 2.7% better performance, respectively. The method also effectively balances colourfulness, sharpness, and contrast, producing the most satisfactory results, as indicated by the highest UIQM score. Additionally, the proposed method introduces more visible edges and effectively restores image details, as demonstrated in the application test, showcasing its suitability for computer vision applications. Overall, the proposed method achieves better natural visual quality with more valuable information and higher contrast, demonstrating its robustness and effectiveness in improving underwater image visibility and quality.

In paper [2] presents an effective and robust underwater image enhancement method based on colour correction and artificial multi-exposure fusion. The method is evaluated using various datasets and compared with several state-of-the-art underwater dehazing and colour correction methods. The experiments are conducted on the Underwater Image Enhancement Benchmark (UIEB) dataset, the Real-world Underwater Image Enhancement (RUIE) dataset, real-world underwater diving scenes dataset, and the Non-homogeneous Hazy and Haze-free Image dataset (NH-HAZE). The proposed method demonstrates superior performance in removing colour distortion, enhancing contrast, and reconstructing lost details in underwater images, as evidenced by both qualitative and quantitative evaluations. Additionally, the method is shown to be suitable for dehazing regular fogged images and improving local feature points matching. The results indicate that the proposed method outperforms existing underwater dehazing and colour correction algorithms in terms of visual quality and computational efficiency.

In paper [3] discusses a novel approach called Comparative Universal Stretching (CUS) for enhancing the quality of underwater images. The method consists of contrast improvement and colour improvement steps, utilizing RGB channel decomposition, colour equalization, and comparative universal stretching to enhance contrast, and the CIE Lab colour model for adaptive stretching to improve colour quality. The approach is compared to standard techniques such as Bianco Prior, Dark Channel Prior, New Optical Model, Integrated Colour Model, and Unsupervised Colour Correction Method, demonstrating superior results in terms of entropy, mean square error (MSE), peak signal to noise ratio (PSNR), HDR-VDP2, and underwater colour image quality evaluation (UCIQE) values. The method is evaluated across eight different underwater image datasets, showcasing its robustness and effectiveness. The datasets used include U45, EUVP, UIEB, LSUI, UFO-120, RUIE, Underwater MOT, and DUO, with the method consistently outperforming other techniques in most datasets, demonstrating its ability to produce high-quality underwater images. The approach's robustness is evident through its superior performance across various underwater image datasets, making it a compelling choice for enhancing underwater images.

[4] Enhancing underwater images is crucial for tasks like object detection and classification, but achieving this clarity is tough due to color casts and haze caused by light absorption and scattering. Existing methods often fall short: traditional ones struggle with highly distorted images, while learning-based approaches frequently separate color correction and dehazing, leading to unnatural results. This paper proposes a novel approach using an iterative network to jointly address both color correction (absorption) and dehazing (scattering) within underwater images. This network iteratively refines these subtasks for better results. A unique color correction module leverages shared information from less distorted channels to correct others, resulting in a more natural color balance. Finally, iterative refinement ensures color balance stays intact while progressively improving both color correction and dehazing. To fully evaluate this new method, further investigation is needed. This includes analyzing existing underwater image degradation models and their impact, comparing the proposed color correction module with others, and assessing the effectiveness of the iterative refinement mechanism in preserving color balance. Ultimately, the goal is to compare this method's performance with state-of-the-art algorithms on various metrics and datasets, including its impact on underwater object detection tasks. By taking this joint approach, the proposed method has the potential to significantly improve underwater image enhancement, unlocking clearer visual information for various applications.

[5] Underwater images suffer from color casts and detail loss due to wavelength-dependent attenuation. Existing methods struggle with restoration and enhancement because they either ignore underwater specifics or make unrealistic assumptions. This paper proposes a novel approach that combines:

* **Attenuation map guided color correction:** Tailors correction for each channel based on its specific attenuation level and applies a piece-wise linear transform for detail preservation.
* **Detail-preserved dehazing:** Separates descattering in the base layer from detail enhancement in residual layers, achieving improved clarity without detail loss.
* **Adaptive Maximum Intensity Prior (MIP):** Uses maximum attenuation identification for robust transmission estimation, leading to better dehazing across diverse environments.

Evaluating this method requires comparing its color correction accuracy and detail preservation to existing techniques, discussing the benefits of the two-step dehazing approach, and assessing the adaptive MIP's performance. Finally, comparing the overall performance with state-of-the-art algorithms will solidify the significance of this novel approach to underwater image enhancement.

[6] Underwater imaging presents significant challenges due to factors such as light attenuation, scattering, and color distortion caused by water. Dehazing underwater images is crucial for applications like underwater exploration, marine biology research, and underwater archaeology. In recent years, various techniques have been proposed to address these challenges and enhance the quality of underwater images.

Quantitative evaluation of dehazing methods is essential for comparing their effectiveness. However, obtaining ground truth medium-free in situ images in underwater environments is impractical. Hence, comparisons are often based on non-reference image quality metrics and contrast quality assessment indexes.

**Metrics for assesment of performance:**

* The Underwater Color Image Quality Evaluation (UCIQE) metric quantifies non-uniform color cast, blurring, and low contrast in underwater images. Panetta and Gao developed three underwater image quality metrics: UICM for color, UISM for sharpness, and UIConM for contrast, which are combined to form the Underwater Image Quality Metric (UIQM).
* The Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE), which predicts image quality based on a support vector regression model trained on an image database.
* The Patch-based Contrast Quality Index (PCQI), which provides accurate predictions of human perception of contrast variations in images.

One recent method introduced for underwater image dehazing is based on a modified Quad-tree-subdivision algorithm for underwater background light estimation and a Color Space Dimensionality Reduction Prior (CSDRP) for haze removal. The background light estimation algorithm subdivides the image into regions and selects the region with the best score based on smoothness and color difference. The haze removal algorithm finds the plane in RGB space, converts the image to UV space, clusters pixels into haze lines, and adjusts pixel intensities based on certain conditions.

Evaluation of the proposed method using metrics such as UCIQE, UIQM, UIConM, BRISQUE, and PCQI demonstrates its effectiveness in improving underwater image quality. Despite some limitations such as artifacts and unexpected stratification in certain cases, the proposed method shows promising results.

[7] Underwater and low-light images have different characteristics, making it challenging to improve their visibility uniformly.The paper proposes a de-hazing and enhancement method for underwater and low-light images.It utilizes Multi-scale Retinex Color Recovery (MSRCR) and guided filtering methods for de-hazing. Additionally, it introduces a white balance fusion global guided image filtering (G-GIF) method to address issues like dim light, color distortion, and loss of edge details.

It compares existing methods such as adaptations of dark channel prior, variational methods, color correction, and deep learning techniques. Similar comparisons are made for non-underwater low-light image processing methods.

The proposed de-hazing method combines MSRCR with guided filtering to address color deviation and faded details. An image degradation model is used to optimize image transmittance, and guided filtering is employed to improve edge details. The paper describes the white balance fusion G-GIF technology for image exposure processing and enhancement, preserving edge details and improving brightness and color.

Qualitative evaluations demonstrate the superiority of the proposed method in terms of de-hazing, color enhancement, and edge detail preservation. Quantitative evaluations using metrics like SNR, entropy, and AVG further validate the effectiveness of the proposed method.

The study [8] assessed the performance of nine techniques, including Water-Net, UColor, GLN-HE (Global-Local Network and Compressed Histogram Equalization), UWCNN, SMBLOT (Statistical Model of Background Light and Optimization of Transmission Map), ATTF-CCR (Adaptive Trigonometric Transformation Function), Image Inverse, JOE-ACDC, and MMLE, on three different depth groups using its self-prepared CDUIE dataset. Various metrics Blind/Reference less Image Spatial Quality Evaluator (BRISQUE), Naturalness Image Quality Evaluator (NIQE), Perception-based Image Quality Evaluator (PIQE), Entropy, and Colourfulness-Contrast-Fog Density (CCF) were utilized to gauge their effectiveness in enhancing underwater image quality. Results showed no consistent superiority among the methods. SIMBLOT consistently achieved the highest CCF score across all depths. Notably, ATTF displayed superior perceptual quality at depths below 1 meter and in the 1–2-meter range based on BRISQUE scores. Conversely, UColor outperformed others in PIQE scores at these depths, while GLN-HE secured the highest entropy score, indicating richer textures and details.

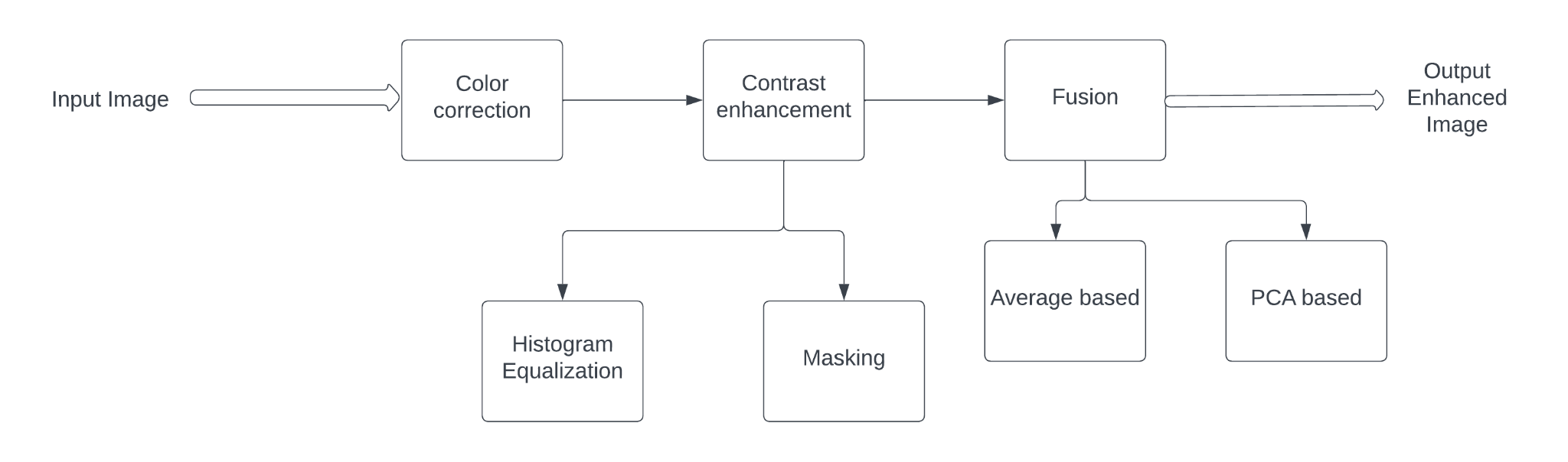
Article [9] proposes a polarization-based image restoration technique suitable for addressing haze and underwater scattering challenges. Initially, the method computes polarimetric images with maximum and minimum variances from four captured polarization images. Then, it estimates transmittance to eliminate scattering light from the background medium of the images with the best and worst variances. Finally, the two images are merged to create a clear image, incorporating colour restoration. Experimental results are evaluated using four objective evaluation indexes: contrast, gray standard deviation, average gradient, and information entropy, validating the effectiveness of this approach in generating clear, restored images in both haze and underwater scattering environments. This method is not dependent on the polarization degree or polarization angle; it is more universal and suitable for scenes with minimal polarized light.

The paper [10] proposes a learning-based restoration approach to enhance the quality of various underwater images. The methodology involves two steps. Firstly, a Convolutional Neural Network (CNN) Regression model learns optimal enhancement parameters for improving the quality of subaquatic images across different scenarios and water conditions. Secondly, based on the identified optimal parameters obtained from the learning process, intensity transformation functions are applied to restore the subaquatic images, resulting in enhanced underwater images. The proposed CNN model includes three convolutional layers, followed by Max Pooling, batch normalization, and ReLU activation. Additionally, two fully-connected layers are utilized with Dropout layers between them. Evaluation on well-known underwater image datasets (U45 and UIEB) and a challenging dataset from the Amazon region (AUID) demonstrates impressive accuracy. Results demonstrate impressive accuracy rates across datasets, with PSNR and SSIM quality metrics indicating significant improvements compared to existing techniques. Additionally, a challenging dataset comprising 276 underwater images from the Urubu River in the Amazon region is proposed.

**III. Proposed method**

Imagine capturing the fleeting grace of a ballerina in mid-pirouette, only for the image to be marred by noise and blur. Or envision a faded family photo, a precious window to cherished memories, obscured by time's relentless march. This is where image restoration steps in, a captivating endeavor where science and artistry coalesce to unveil the potential hidden within every pixel.

Our proposed method, akin to a maestro conducting a masterful symphony, orchestrates a harmonious blend of established and burgeoning techniques, each playing a distinct role in this transformative process.



**Histogram Equalization: The Masterstroke of Contrast**

Picture a cherished landscape photograph, its once vibrant hues muted by exposure issues. Enter histogram equalization, the first brushstroke in this restoration journey. Analyzing the distribution of pixel intensities, it meticulously redistributes them with the precision of a master artist, breathing life back into the scene. Shadows gain definition, revealing hidden details with newfound clarity. Imagine dark valleys bathed in moonlight, or sunlight illuminating the intricate details of a weathered stone wall. Each subtlety, once concealed, is unveiled, enriching the narrative and emotional impact of the image.

**Color Enhancement: A Palette of Possibilities**

Color inconsistency, a common foe in degraded images, is no match for our vibrant palette of color enhancement techniques. Saturation adjustment acts like a skilled colorist, delicately adjusting vibrancy to infuse the scene with life and energy. Imagine restoring faded wildflowers to their original brilliance, or breathing life back into the rosy cheeks of a loved one in a cherished family portrait. Brightness and contrast adjustments become the chiaroscuro masters, manipulating light and shadow to reveal a wider dynamic range, richer emotions, and a more dramatic composition. White balance correction, like a skilled photographer adjusting for lighting conditions, ensures accurate color representation, preserving the scene's true essence. Finally, tone mapping, similar to a skilled printer balancing ink density, enhances the tonal depth and richness, particularly in HDR images, creating an image that pops with depth and realism.

**Fusion Methods: Weaving the Best of Many Worlds**

Imagine weaving several damaged tapestries into a single, magnificent artwork. Fusion methods achieve this digital artistry by combining information from multiple images or sources. For aligned images with similar characteristics, average fusion acts like a skilled tailor, seamlessly blending them to create a composite with improved noise reduction or dynamic range. Imagine stitching together multiple exposures for stunning HDR photography, revealing details previously lost in shadows or highlights. But when information is diverse or noise levels vary, PCA-based fusion steps in, meticulously analyzing each input like a discerning curator. It extracts the most significant elements, discarding noise and redundancy, and then weaves them together to create a tapestry richer in information and detail than any single source could offer. Imagine combining multiple medical scans from different modalities to reveal a more comprehensive picture of an internal structure.

**Deep Learning's Brushstrokes: Adding a Touch of Magic**

While our core techniques form the foundation, the future beckons with the potential of Deep Neural Networks (DNNs). Imagine training these digital artists on vast datasets of diverse images, enabling them to learn complex relationships and perform data-driven restoration. Think of them as the innovative apprentices, eager to learn from the masters and push the boundaries of image restoration. DNNs could become the master colorists, subtly enhancing colors with unparalleled precision, or even generate entirely new, realistic images that seamlessly blend with the restored scene. Imagine restoring a missing section of a historical painting with astonishing accuracy, or bringing a grainy historical photograph to life with stunning detail.

**Seeing Through Human Eyes: Beyond Technical Metrics**

The true mark of success lies in exceeding mere technical metrics like PSNR or SSIM. We embrace advanced measures like LPIPS and BRISQUE, which align with human visual perception, ensuring the restored image resonates emotionally and feels "right" to the human eye. Imagine viewing a restored portrait that not only accurately depicts the physical features but also captures the essence of the individual's expression and personality. This subjective evaluation ensures that the beauty and character of the original scene are preserved, not just pixel-perfect replication.

**Domain-Specific Tailoring: A Bespoke Suit for Every Image**

The needs of a medical scan differ vastly from those of a historical photograph. Our approach isn't a one-size-fits-all solution. We meticulously tailor our techniques to each domain, incorporating domain knowledge and specialized algorithms. Imagine applying denoising techniques specifically designed for medical scans to preserve crucial details, while utilizing color correction methods optimized for historical photographs to maintain their stylistic integrity. This ensures that every image receives the specific treatment it deserves, maximizing the restorative potential while respecting its unique characteristics.

**Efficiency in Mind: Speed Meets Quality**

Imagine near-instantaneous restoration of medical X-rays for real-time diagnosis, or rapid historical photo restoration for educational purposes. By prioritizing efficiency, we ensure our method can be applied to various use cases, from real-time applications to large-scale image restoration projects, democratizing access to this transformative technology.

**Beyond Technology: Ethical Considerations and Human Impact**

As we delve deeper into the realm of artificial intelligence, ethical considerations must be at the forefront. Imagine using deep learning techniques to manipulate reality in subtle ways, or perpetuate biases present in training datasets. We must actively address these concerns, ensuring our methods are used responsibly and ethically, serving humanity's progress while respecting the integrity of the originals. This includes careful selection and curation of training data, the development of explainable AI models, and transparent communication about the limitations and potential biases of our techniques.

**Collaboration: A Chorus of Diverse Expertise**

Imagine a world where artists, scientists, historians, and technologists collaborate to push the boundaries of image restoration. We envision open-source platforms and shared datasets fostering innovation and collective problem-solving. Imagine artists providing invaluable feedback on the aesthetics and emotional impact of restored images, while historians guide the process to ensure historical accuracy and cultural sensitivity. Such collaborations can accelerate progress, ensure wider societal benefits, and foster a responsible and ethical approach to this powerful technology.

**The Final Crescendo: Unveiling a Brighter Future**

Our proposed image restoration method is not just a technical solution; it's a symphony of techniques designed to unveil the hidden beauty and information within every image. By combining the precision of established methods with the innovative potential of deep learning, while staying true to ethical principles and fostering collaboration, we aim to unlock a brighter future for image restoration. Imagine historical photographs brought back to life, enriching our understanding of the past. Imagine medical scans revealing critical details with unprecedented clarity, leading to faster and more accurate diagnoses. Imagine artistic masterpieces restored to their former glory, inspiring future generations. The possibilities are endless, and we are just beginning to compose the symphony of image restoration, a harmony of technology, artistry, and ethics that promises to unveil the hidden potential within every pixel.

**IV. Data Set**

Underwater Image Enhancement Benchmark (UIEB) including 950 real-world underwater images, 890 of which have the corresponding reference images. We treat the remaining 60 underwater images which cannot obtain satisfactory reference images as challenging data. Using this dataset, we conduct a comprehensive study of the state-of-the-art underwater image enhancement algorithms qualitatively and quantitatively.

**Data Set Access Link:** <https://opendatalab.com/OpenDataLab/UIEB>

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