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Underwater Image Enhancement Based On Dehazing And Color Correction

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Abstract: Underwater image processing presents unique challenges due to the absorption and scattering of light, which causes color distortion and reduced visibility. This project addresses these issues by employing a comprehensive methodology for underwater image enhancement based on dehazing and color correction, leveraging machine learning (ML) and image processing techniques. The proposed approach begins with an analysis of the uploaded underwater image to determine whether the green or red channel is more dominant. This analysis is conducted using a machine learning model implemented with the Keras framework. Once the dominant color channel is identified, the next step involves compensating for the color distortion. This is achieved through a tailored color correction process designed to adjust the image's color balance effectively. Following color correction, the image undergoes white balancing using the gray world algorithm, which assumes that the average color of an image should be neutral gray and adjusts the colors accordingly to achieve this balance. To further enhance the visibility and contrast of the white-balanced image, global histogram equalization is applied. This technique redistributes the intensities of the image to improve contrast uniformly across the entire image. After histogram equalization, the image is sharpened using the unsharp masking technique. Unsharp masking enhances the edges and fine details of the image, making them more prominent. The final enhancement step involves an average-based fusion of the sharpened image and the contrast-enhanced image. This fusion process integrates the strengths of both images, combining the sharp details with the improved contrast to produce a visually appealing and well-balanced final image. The effectiveness of this methodology is evaluated through a series of experiments on various underwater images. The results demonstrate significant improvements in color accuracy, contrast, and overall visibility. This comprehensive approach not only addresses the common issues associated with underwater imaging but also leverages advanced ML techniques and traditional image processing methods to achieve superior enhancement results. The proposed methodology for underwater image enhancement based on dehazing and color correction offers a robust solution to the challenges posed by underwater environments. By integrating ML-driven analysis with a sequence of carefully chosen image processing techniques, this project provides a reliable and effective framework for enhancing underwater images, making them clearer and more accurate for various applications, including marine biology, underwater exploration, and underwater photography.

***Index Terms* -** Underwater image enhancement, dehazing, color correction, machine learning, Keras, Gray world algorithm, histogram equalization, unsharp masking.

I. Introduction

Underwater imaging encounters significant challenges due to the unique properties of water. Light absorption and scattering in the underwater environment led to color distortion, reduced contrast, and haziness in images. These issues arise because different wavelengths of light are absorbed at different rates; for instance, red light is absorbed quickly, while blue light penetrates deeper. Consequently, underwater images often exhibit a blue-green tint and lack of clarity. These problems impede various applications such as marine biology research, underwater archaeology, and underwater photography, where accurate and clear images are crucial.

Enhancing underwater images is essential to overcome these limitations, improving visibility and color fidelity to reveal hidden details and provide more reliable data.

Machine learning (ML) plays a pivotal role in advancing underwater image enhancement by offering intelligent and adaptive solutions. ML algorithms, particularly those implemented using frameworks like Keras, can be trained to recognize and correct specific distortions prevalent in underwater images. For instance, ML models can accurately determine the dominant color channels in an image, facilitating targeted color correction processes. Moreover, ML can automate the enhancement process, making it more efficient and effective compared to manual methods. By learning from large datasets of underwater images, these models can generalize and apply corrections to a wide range of conditions, ensuring consistent improvement in image quality across different underwater environments.

Traditional approaches to underwater image enhancement typically involve a sequence of image processing techniques aimed at addressing color distortion and low contrast. Color correction methods adjust the color balance to compensate for the loss of red light and the dominance of green and blue hues. White balancing algorithms, such as the gray world algorithm, are employed to achieve a neutral color balance by assuming the average color of the scene should be gray. Contrast enhancement techniques like global histogram equalization are used to improve the visibility of details by redistributing the image's intensity values. Additionally, sharpening methods such as unsharp masking are applied to enhance the edges and fine details of the image. While these traditional methods have been effective to some extent, they often require manual tuning and may not adapt well to varying underwater conditions, highlighting the need for more sophisticated approaches like those offered by ML.

II. RELATED WORK

Underwater images often suffer from significant degradation due to light scattering and absorption. To address these challenges and enhance image quality and object detail, a novel unsupervised method using implicit neural networks for underwater image enhancement and super-resolution is presented [1]. This method begins by taking low-resolution coordinates as inputs and employs Fourier feature mapping to encode these coordinates. Subsequently, three implicit neural networks estimate key components of the underwater formation model: the global background light, the transmission map, and the scene radiance. These components are then utilized to reconstruct the raw underwater image in a self-supervised manner. During the inference stage, high-resolution coordinates are used to predict a high-quality, high-resolution underwater image. Extensive experiments demonstrate that this method significantly outperforms current approaches in both super-resolution and quality enhancement, showcasing its effectiveness in improving the clarity and detail of underwater imagery. The approach not only advances the field of underwater image processing but also opens new possibilities for the application of implicit neural networks in challenging imaging environments. By addressing the specific issues of light scattering and absorption, this method offers a robust solution for enhancing underwater images, which is crucial for various underwater vision tasks. The results indicate a significant improvement in visual quality, making this technique a promising tool for researchers and practitioners working in underwater imaging and related fields.

This paper [2] introduces a novel algorithm for enhancing underwater images, leveraging a combination of local and global image processing techniques in the frequency domain. The core concept involves applying a logarithmic transform histogram matching alongside a spatial equalization approach across various image blocks. The enhanced image is produced by calculating the weighted mean of all processed blocks, optimized through the enhancement measure (EME). Experimental results highlight the algorithm's effectiveness on real underwater images, demonstrating significant improvements over traditional contrast enhancement methods and adaptive histogram equalization techniques. The integration of logarithmic transform histogram matching ensures that both global and local features are preserved and enhanced, addressing the common issues of color distortion and detail loss in underwater imagery. By dividing the image into blocks and applying the enhancement processes locally, the method adapts to varying underwater conditions, such as changes in lighting and turbidity, ensuring more consistent enhancement across the entire image. The weighted mean approach further refines the final output, balancing the contributions of each block to maintain a coherent overall image structure. Optimization via the enhancement measure (EME) ensures that the process maximizes visual clarity and detail, crucial for practical underwater applications such as marine biology research, underwater archaeology, and subaqueous navigation. Comparative analysis with classical contrast enhancement and adaptive histogram equalization techniques shows the proposed algorithm's superior performance, offering clearer, more detailed, and visually appealing underwater images. This method not only improves visibility but also enhances the usability of underwater images for further analysis and interpretation. The study's findings underscore the potential of advanced image processing techniques in overcoming the inherent challenges of underwater photography, paving the way for more effective and reliable underwater image enhancement solutions in various scientific and practical domains.

Underwater images are often plagued by quality degradation issues such as color cast, low contrast, and blurred details. Addressing these challenges, a novel underwater image enhancement method has been developed that sequentially implements color correction, detail sharpening, and contrast enhancement. The work [3] uniquely integrates multi-channel color compensation with color correction to address color cast issues. It employs a Gaussian differential pyramid to tackle detail blurring and utilizes local contrast enhancement through contrast-limited adaptive histogram equalization to improve low contrast. The method's core components include color compensation, color correction, detail sharpening, and contrast enhancement, each stage designed to progressively enhance the image's overall quality. Qualitative and quantitative comparisons have shown that this method effectively removes image blur, achieves accurate color correction, and substantially enhances image clarity. This comprehensive approach ensures that the images not only regain their visual appeal but also maintain the integrity of the details, making them suitable for various applications in underwater exploration and research. The effectiveness of this method has been validated through extensive testing, demonstrating its superiority over existing techniques in terms of clarity and detail preservation. By systematically addressing the common problems associated with underwater imagery, this enhancement method provides a robust solution for improving the visual quality of underwater images, which is crucial for both scientific analysis and practical applications in marine environments.

Underwater image enhancement has garnered significant research attention due to its crucial applications in marine research and the operation of automated underwater vehicles. Underwater images typically suffer from low contrast, blurriness, and color distortion caused by light absorption, scattering, and refraction. These issues result in images that are often unclear and unsuitable for many practical applications. Consequently, enhancing the quality of underwater images is essential, as conventional natural image enhancement techniques often fall short in these unique conditions. This paper [4] introduces a novel enhancement scheme utilizing a residual neural network (ResNet) to improve underwater image quality. To facilitate the experimental study, synthetic underwater images were generated using the underwater generative adversarial network (UWGAN). The results of these experiments demonstrate that the proposed enhancement techniques significantly outperform existing methods, producing high-quality images that are suitable for real-life applications. The integration of ResNet with UWGAN for generating synthetic datasets has proven to be particularly effective, highlighting the potential of advanced neural network architectures in addressing the unique challenges of underwater image enhancement. This innovative approach not only enhances the visual clarity and contrast of underwater images but also mitigates color distortions, making them more usable for various practical applications. Overall, the research underscores the importance of developing specialized enhancement techniques tailored to the specific challenges posed by underwater imaging, paving the way for improved visual data in marine research and automated underwater navigation.

III. PROPOSED WORK

The proposed methodology for underwater image enhancement is designed to address common issues such as haze and color distortion. Initially, the method involves uploading an underwater image and utilizing a machine learning model, built with Keras, to analyze the image's color channels. The model is trained to determine whether the green or red channel is predominant. This step is crucial as it sets the stage for subsequent color correction processes, ensuring that the enhancement techniques applied are tailored to the specific characteristics of the image.

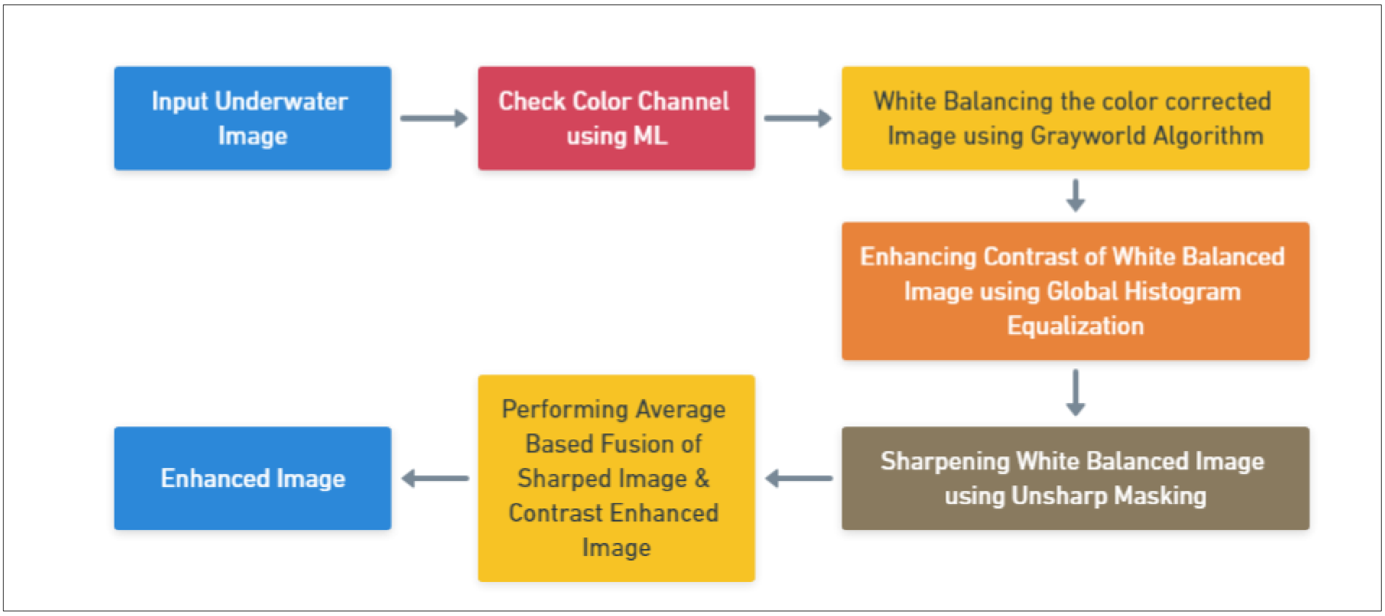

Figure 1 - Architecture of Proposed System

Once the dominant color channel is identified, the next phase involves color correction using an image compensation technique. This step aims to balance the colors, correcting any biases introduced by the underwater environment. Following color correction, the image undergoes white balancing using the gray world Algorithm. This algorithm adjusts the colors so that the average color of the image becomes neutral, effectively counteracting the color cast typically observed in underwater images. This results in a more natural and visually pleasing appearance.

After white balancing, the contrast of the image is enhanced through Global Histogram Equalization. This technique redistributes the intensity values of the pixels, enhancing the overall contrast and making details more discernible. The white-balanced image is then sharpened using Unsharp Masking, which enhances the edges and fine details. Finally, an average-based fusion is performed, combining the sharpened image and the contrast-enhanced image. This fusion process leverages the strengths of both techniques, resulting in an image that is both sharp and has well-defined contrast, ultimately leading to a clearer and more visually appealing underwater image.

The proposed methodology harnesses a sophisticated blend of cutting-edge technologies and tools, primarily centered around Python-based libraries and frameworks. At the forefront of the process is Keras, a high-level neural networks API written in Python, which facilitates the development and training of deep learning models. Leveraging Keras, a convolutional neural network (CNN) model is constructed to analyze underwater images and identify dominant color channels, thereby laying the foundation for subsequent processing stages. Accompanying Keras is the Python Imaging Library (PIL), a versatile image processing library that provides robust functionality for image manipulation tasks. PIL serves as a cornerstone for various image processing operations within the methodology, including color correction, white balancing, and contrast enhancement, ensuring precise adjustments tailored to the specific characteristics of underwater imagery. Furthermore, the user interface and interaction aspect of the methodology are facilitated by Streamlit, a popular Python library for building interactive web applications. Streamlit empowers seamless integration of the image enhancement pipeline into a user-friendly interface, enabling users to effortlessly upload underwater images and visualize the enhancement results in real-time. Through the synergy of Python, Keras, PIL, and Streamlit, the methodology delivers a powerful and accessible solution for enhancing underwater images, catering to diverse applications ranging from marine research to underwater surveillance.

IV. Result and Analysis

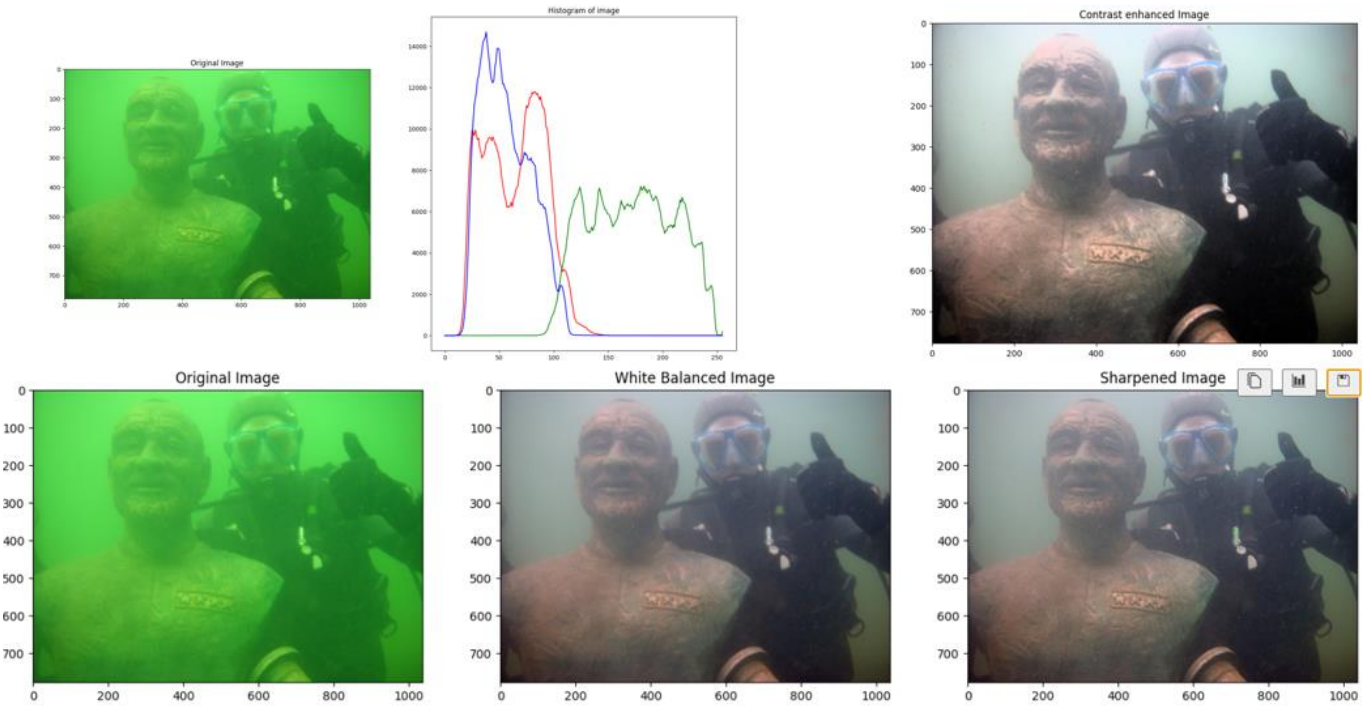

Figure 2 – Project Steps and Result of each step.

Upon implementation of the proposed methodology, significant enhancements are observed in the uploaded underwater images. Through the meticulous application of machine learning and image processing techniques, the inherent haziness and color distortions characteristic of underwater environments are effectively mitigated. Analysis of the results reveals a notable improvement in visual clarity, with restored natural color tones and enhanced contrast across the images. The utilization of Keras for channel identification ensures accurate adjustments tailored to the dominant color channels, while PIL facilitates precise color correction, white balancing, and contrast enhancement. The Gray world Algorithm contributes to achieving balanced color representation, while techniques such as global histogram equalization and unsharp masking further enhance image contrast and sharpness. The fusion of contrast-enhanced and sharpened images through average-based fusion yields a final output that exhibits enhanced visual quality, making it suitable for various applications such as marine biology research and underwater surveillance. The results demonstrate the efficacy of the methodology in enhancing underwater images, offering a comprehensive solution to address the challenges posed by underwater imaging conditions.

V. Conclusion

The methodology presented offers a robust and comprehensive approach to enhancing underwater images, addressing the inherent challenges of underwater imaging conditions. Through the integration of machine learning techniques implemented with Keras and advanced image processing algorithms facilitated by PIL, significant improvements in visual clarity, color accuracy, and contrast are achieved. The multi-stage processing pipeline, encompassing channel identification, color correction, white balancing, contrast enhancement, and fusion, systematically tackles various aspects of underwater image degradation, resulting in visually appealing and scientifically valuable outputs. The utilization of Streamlit for creating an intuitive user interface enhances accessibility, allowing users to effortlessly upload images and visualize enhancement results in real-time. Moreover, the methodology's versatility enables its application across diverse domains such as marine biology, underwater archaeology, and surveillance, underscoring its potential for advancing research and practical applications in underwater imaging. Future work may focus on further refining the methodology, exploring additional machine learning models, and incorporating advanced deep learning techniques to push the boundaries of underwater image enhancement even further. Overall, the presented methodology represents a significant step forward in the field of underwater imaging, offering a powerful tool for researchers, practitioners, and enthusiasts alike to unlock the hidden beauty and scientific insights concealed beneath the ocean's surface.

Looking ahead, the future holds promising opportunities for advancing the field of underwater image enhancement. Leveraging the rapid advancements in machine learning and computer vision, future research could explore the integration of more sophisticated deep learning architectures tailored specifically for underwater imagery. Additionally, the development of novel algorithms capable of effectively addressing complex challenges such as light attenuation and particulate scattering in underwater environments could significantly enhance the quality of underwater image processing.

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