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Enhancing Underwater Images through Hybri Color Channel Correction with CLAHE and DSIHE Algorithms

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Abstract—Our approach to underwater image enhancement draws inspiration from hybrid algorithms. We initially focus on color correction of underwater images by resolving the differ-ences between superior and inferior color channels. We achieve this by compensating for deficiencies in the lower channels using custom attenuation matrices. After color correction, we improve both the global and local contrast of images. Global contrast en-hancement is performed using an iterative thresholding approach based on a dual histogram, while local contrast enhancement uses a limited histogram method based on the Rayleigh distribution. These techniques result in contrast-enhanced versions of the image both globally and locally. To combine the strengths of global and local contrast enhancement, we use a multi-level fusion strategy. This provides comprehensive image enhancement using enhancements at different scales. Next, we present a new algorithm for underwater image restoration. This algorithm overcomes the limitations of traditional earlier dark channel algorithms by incorporating an improved background light esti-mation method. This method aims to mitigate the effects of light and white objects in water, thereby improving the accuracy of background light estimation. Additionally, our algorithm includes an improved automatic white balance algorithm to reduce color distortion. This allows for cleaner images with color correction facilitated by Contrast Limited Adaptive Histogram Equalization (CLAHE) and Dual Subframe Histogram Equalization (DSIHE) techniques. Overall, our approach offers a comprehensive solu-tion for enhancing underwater images, solving color correction, contrast enhancement and restoration issues. The integration of new techniques and algorithms together with thorough evaluation underlines the effectiveness and credibility of our approach.

Index Terms—Color correction, contrast enhancement, under-water image enhancement, underwater imaging.

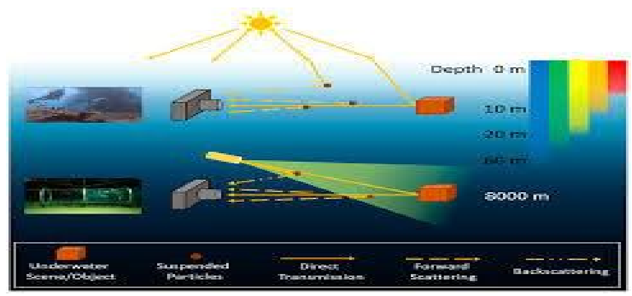
I. Introduction

Underwater image processing has become an increasingly active field within the broader realm of image processing, with researchers dedicating considerable efforts to its exploration. Its applications range from mapping underwater environments to tasks like fish detection and monitoring corrosion on sub-

To tackle these challenges, researchers focus on two main approaches: image restoration and enhancement. Image restoration aims to understand and compensate for factors causing image degradation, such as noise and light attenuation, thereby restoring image quality. Following restoration, image enhancement techniques are applied to further improve visual clarity, often by enhancing contrast. Integrating these processes into a single algorithm streamlines post-processing, reducing the time needed for subsequent analysis.

Underwater images commonly suffer from issues like color distortion, low contrast, and blurred details, primarily due to light scattering and absorption by particles in the water and selective attenuation of light wavelengths. Addressing these challenges requires innovative approaches.

In Fig.1 Underwater image processing involves overcoming obstacles such as noise and light attenuation to enhance image quality. By combining restoration and enhancement techniques, researchers aim to mitigate these challenges and achieve clearer, visually appealing underwater imagery.



merged structures. However, underwater imagery faces significant challenges, including noise from suspended particles and light attenuation with depth, which degrade image quality and hinder effective information extraction.

Fig. 1. Image Capturing Process

II. Literature Survey

In a study cited as [4], the Dark Channel Prior algorithm is adapted for underwater environments with adjustments tailored to the unique characteristics of the setting. Specifically, mod-ifications are made to account for the increased attenuation of the red channel intensity in water compared to other wavelengths. The Dark Channel Prior equation is then applied to the input color channels using appropriate parameters. The study demonstrates the algorithm's effectiveness in removing haze from images captured under artificial lighting. However, it is noted that the algorithm tends to oversaturate the red channel in the final output, failing to entirely eliminate haze from underwater images.

Another referenced study [8] provides an overview of the principles and outcomes of reviewed papers but lacks quan-titative or qualitative assessments based on image correction parameters. Conversely, studies such as [9] and [10] categorize underwater image processing techniques and evaluate their performance in enhancing image quality. However, the absence of quantitative data hampers direct comparisons between pa-pers, primarily relying on user application perspectives.

In contrast, [7] proposes a method to enhance underwater image contrast by stretching the RGB components and ad-justing the HSI components. While this approach enhances contrast, the resulting images may appear artificial and do not address issues related to non-uniform scene lighting underwa-ter.

Significant publications such as ”State of the Art of Restora-tion and Image Enhancement Methods” [8], ”A Survey on Underwater Image Enhancement Techniques” [9], and ”Under-water Optical Image Processing: A Comprehensive Review” [10] contribute to the understanding of the field.

The hardware approach, as discussed in ”Recovery of Underwater Visibility and Structure by Polarization Analysis” [11] by Y. Schechner and N. Karpel, tackles image degradation in underwater settings by capturing images with a polarizer set at various orientations. This method capitalizes on the partial polarization of light, yet it incurs higher operational costs, requires skilled personnel, and involves longer development and processing times compared to software-based approaches.

On the software front, ”Single Image Dehazing by Multi-Scale Fusion” [12] introduces a technique utilizing two hazy images for processing. This method incorporates white bal-ancing and contrast enhancement, filtering important features of the images based on luminance, chromaticity, and saliency, and effectively combining information from the two images at the pixel level. While more computationally intensive and challenging to implement, this fusion-based multiscale strategy can produce accurate outcomes in dehazing images using only a single degraded input image, provided the right weight maps and inputs are used.

III. Methodology

In the propsed methodology,Our study introduces an inno-vative technique for enhancing underwater imagery, free from the constraints of prior knowledge and specialized hardware. This method successfully addresses the common challenges associated with underwater images, notably color distortions and low contrast.

A. Histogram Equalization

To enhance visual quality, it's essential to devise color image enhancement techniques that enhance contrast [15]. Among the prominent enhancement methods, intensity his-togram equalization (HE) is widely employed. HE stretches a concentrated histogram to achieve a uniform histogram. For an eight-bit gray level image with dimensions of M×N, the probability of occurrence of intensity level can be approxi-mated as follows.

$$p_i(I_k) = \frac{n_k}{MN} \quad k = 0,1,2,3.....255$$

The intensity transformation is then computed by applying the following formula:

$$c_k = T(I_k) = 255\sum_{j-0}^{k} p_I(I_j)$$

$$= \frac{255}{MN}\sum_{j-0}^{k} n_j \quad k-0,1,2,3,4...255$$

Therefore, the histogram equalization (HE) image is ob-tained by converting each pixel in the input image with intensity level into a corresponding pixel with level in the output HE image. This normalization process is crucial in image processing as it adjusts the range of pixel intensity values according to the algorithm's requirement. Consequently, it enhances the distribution of intensity, thereby improving global contrast in the image.

B. Contrast Stretching

In response to the restricted variation observed in under-water images, the dynamic range of the histogram tends to be narrow. To counteract this issue, a complexity extension technique is employed to redistribute pixel values around 0 and 255. The contrast stretching algorithm employs a linear scaling function for the pixels, as depicted below [16]:

$$I_N(x, y) = \left(I\ (x, y) - I_{Min}\right) \times \left(\frac{Id_{Max} - Id_{Min}}{I_{Max} - I_{Min}}\right) Id_{Min},$$

where:

NIxy= normalized pixels intensity after contrast stretching;

I x y is the pixel intensity value before contrast stretching.;

I is the lowest intensity of the parent image; The contrast stretching operation relies on the assumption that the image signal has a wide enough dynamic range.In underwater imagery, where contrast is often limited, traditional contrast stretching techniques may not suffice. To address this, methods retrieve minimum and maximum pixel intensities directly from the original image, adapting the approach to better suit the unique characteristics of underwater scenes. Fig.2 This flow represents the process of enhancing the image from taking a raw image to an enhanced image and performance evaluation metrices.

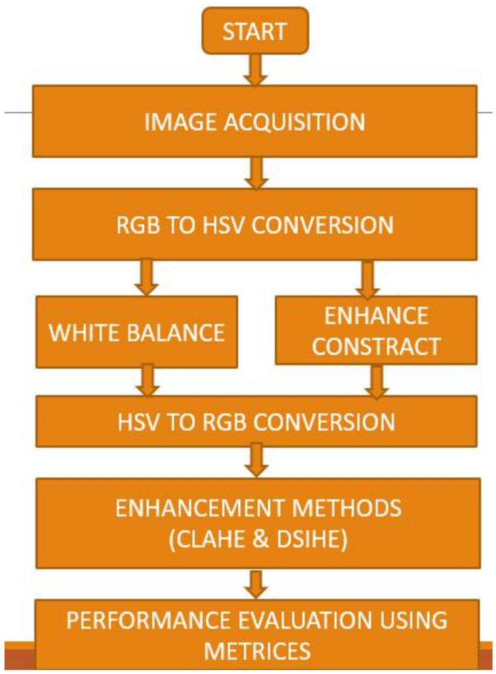


Fig. 2. Image Enhancement Flow

- Start
- Acquiring the image
- Pre-processing based on CLAHE and DSIHE
- Balancing the color (color correction)
- Conversion of RGB to Lab and its inverse
- Post Processing using bilateral filtering
- Histogram analysis
- Performance

metrics C. CLAHE:

While AHE can significantly enhance local contrast, it can also lead to noise amplification and over-enhancement of small local details, which may result in artifacts. CLAHE addresses this issue by limiting the contrast enhancement within each tile. This is achieved by clipping the histogram at a specified limit, preventing excessive amplification of intensity values.

D. Implementation:

In implementation, CLAHE typically involves the following steps: Divide the image into non-overlapping tiles. The image is divided into non-overlapping tiles, and histogram equalization is applied to each tile independently. To control the contrast enhancement, the histogram of each tile is then clipped based on a specified clip limit, ensuring balanced enhancement across the image. This approach allows for localized contrast enhancement while preventing over-amplification of noise or artifacts. Interpolate or blend the histogram-equalized tiles to reconstruct the final enhanced image.

Parameters: - CLAHE requires two main parameters: -

E. Clip Limit:

The clip limit parameter regulates the maximum slope of the cumulative distribution function (CDF) during his-togram clipping, effectively constraining the extent of contrast enhancement applied to individual tiles. By imposing this limit, the algorithm ensures that enhancements remain within acceptable bounds, preventing over-amplification of contrast and preserving image fidelity.

F. Tile's Size:

The tile's size parameter determines the dimensions of the regions into which the image is divided for histogram equalization. Smaller tile sizes enable the capture of finer local details in the image, but they may also lead to increased computational complexity due to the larger number of tiles that need to be processed. Balancing between smaller tiles for detailed enhancement and computational efficiency is crucial in optimizing the performance of the algorithm.

G. Applications:

CLAHE is widely used in image processing applications where enhancing local contrast while preserving overall image characteristics is essential. It finds applications in medical imaging, remote sensing, surveillance, and more.Contrast Limited Adaptive Histogram Equalization (CLAHE) enhances image contrast while preserving local details by employ-ing adaptive histogram equalization with controlled contrast. This method enhances visual quality by effectively balancing contrast improvement without introducing notable artifacts, ensuring a more natural and visually appealing result.

H. DSIHE:

DSIHE (Dualistic Sub-Image Histogram Equalization) ex-tends the traditional histogram equalization technique by divid-ing the image into sub-images and equalizing their histograms independently. This approach enhances image contrast by effectively addressing local variations in intensity, resulting in improved visual clarity and detail without significant distortion or artifacts.

I. Color Space Conversion:

Convert the RGB color image to a suitable color space, such as YCbCr or HSV, where intensity information is separated from color information. This separation is essential because histogram equalization should typically be applied to the intensity component only.

J. Sub-Image Division:

Divide the intensity component of the image into non-overlapping sub-images or tiles. These tiles can be of uniform size or may vary depending on the implementation. The purpose of dividing the image is to perform histogram equal-ization separately on each sub-image, allowing for localized contrast enhancement.

K. Histogram Equalization:

Apply histogram equalization independently to each sub-image. This involves computing the histogram of intensity val-ues within each sub-image and then applying a transformation to spread out the intensity values evenly across the intensity range.

L. Interpolation or Blending:

Depending on the implementation, the histogram-equalized sub-images may need to be interpolated or blended back together to reconstruct the final enhanced image. This step ensures seamless transitions between adjacent sub-images and mitigates visible artifacts at the boundaries of the tiles, thereby maintaining overall image coherence and enhancing the visual quality of the final result.

M. Color Space Inverse Conversion:

If necessary, convert the histogram-equalized intensity component back to the final enhanced color image is obtained by transforming the original color space, preserving the color integrity while incorporating the enhancements achieved through contrast equalization techniques, resulting in a visually improved representation of the original scene.

N. Parameter Adjustment:

DSIHE involves parameters like the number and size of sub-images, impacting the quality of the enhanced image, necessitating adjustments based on input image characteristics and desired enhancement levels. It aims to enhance color image contrast while minimizing artifacts and preserving color fidelity. By conducting histogram equalization on localized in-tensity regions, DSIHE improves visual quality across diverse applications, including medical imaging, satellite imagery, and digital photography.

IV. Results and Discussions

The evaluation of enhancement methods relies heavily on Image Quality Measurement (IQM), which is instrumental in assessing the effectiveness of various image processing algorithms, including enhancement, deblurring, and denoising. IQM enables the quantitative evaluation of algorithm performance by measuring the quality and performance metrics of the processed output image, providing valuable insights into the efficacy of these methods.

A. Qualitative Evaluation

Qualitative aspects are inherently abstract and cannot be measured directly or precisely, as they encapsulate aspects of reality that defy precise quantification. Instead, qualitative evaluation relies on human observations, serving as the pri-mary means of assessment in fields like meteorological re-search, where subjective insights are crucial for understanding complex phenomena and nuances beyond quantifiable metrics.

B. Quantitative Evaluation

Quantitative evaluation involves proper way of computation and numerical expression, enabling researchers to predict the future events or quantities with precision [22]. This evaluation approach entails selecting specific metrics tailored to assess image quality, providing objective measures for evaluating the performance of image processing algorithms.

C. Peak Signal-to-Noise Ratio (PSNR):

PSNR (Peak Signal-to-Noise Ratio) serves as a mathematical metric for image quality, gauging the pixel difference between two images [20]. It offers an estimation of the enhanced image's quality relative to the original image. PSNR considers signal strength and is calculated using the equation: $PSNR = 20 * \log10(R / RMSE)$, where R denotes the maximum fluctuation or value in the image, typically 255 for an 8-bit unsigned number.

D. Root Mean Square Error (RMSE):

$$RMSE = \mathrm{sqrt}((1 / N) * \mathrm{sum}((I - I')^2))$$

In the equation for PSNR, where N represents the total number of pixels in the image, I denotes the original image, and I' signifies the enhanced image. RMSE (Root Mean Square Error) quantifies the average difference between the pixel values of the original and enhanced images, providing a numerical measure of the discrepancy between the two images.

E. Contrast:

Contrast denotes the disparity in luminance or color that enables an object to stand out from its surroundings. In visual perception, contrast is determined by variations in color and brightness between the object and other elements within the same field of view. These quantitative evaluation methods yield valuable insights into the performance of enhancement techniques, aiding in the refinement of image processing algorithms. The proposed methods exhibit satisfactory outcomes for underwater images, with some images showcasing in the paper from the complete dataset. While Histogram Equalization yields average results and Contrast Stretching produces unclear output, CLAHE and DSIHE proposed methods offer superior outcomes for enhancing underwater image quality.

The notion of contrast, pivotal in visual perception, encap-sulates the discernible difference in luminance or color that distinguishes an object from its surroundings. This distinction arises from the interplay of color and brightness variations between the object and adjacent elements within the field of view.

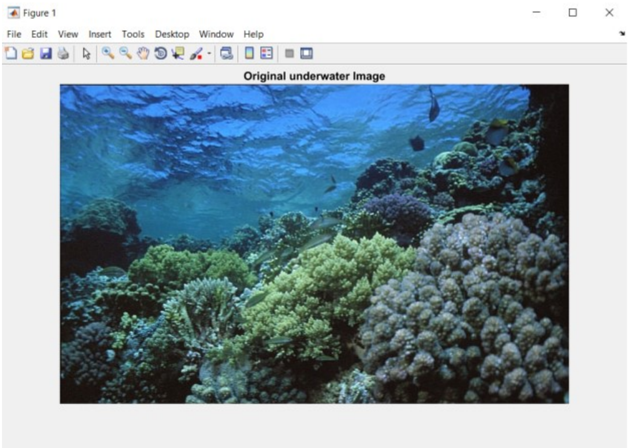


Fig. 3. Original Image

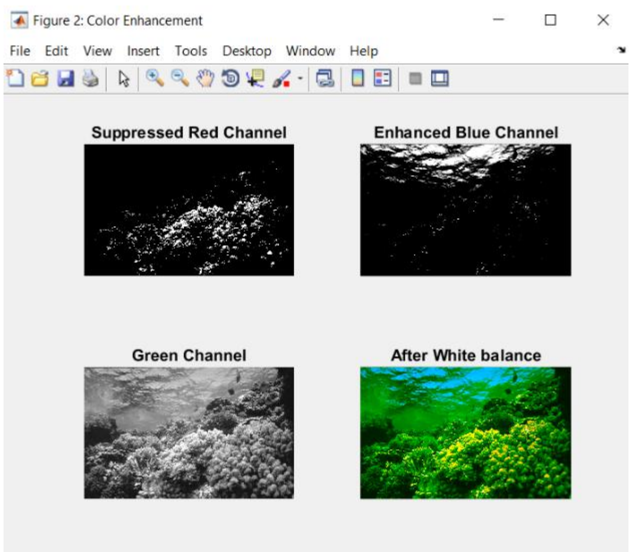


Fig. 4. Enhanced Image

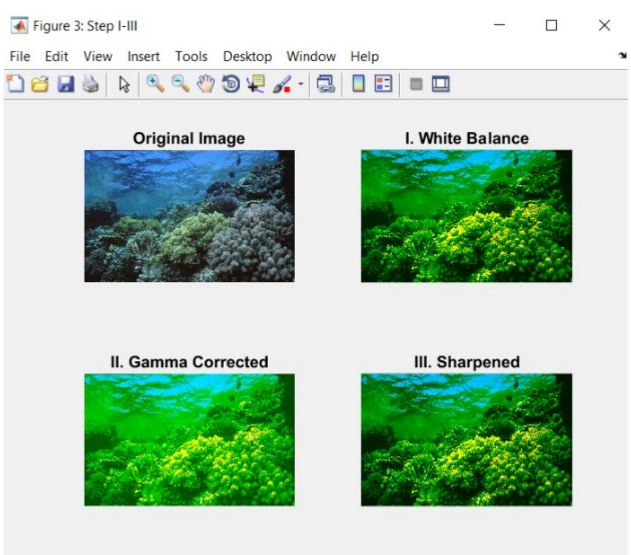


Fig. 5. Gamma Corrected Image

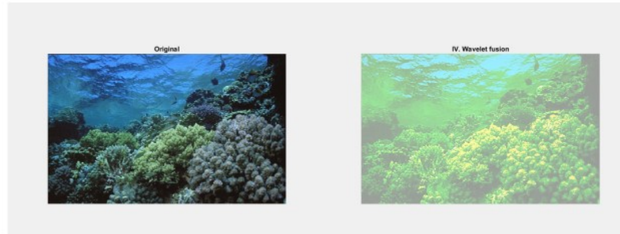


Fig. 6. Fused Image

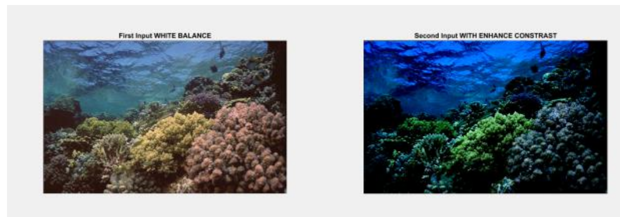


Fig. 7. White Balanaced Image

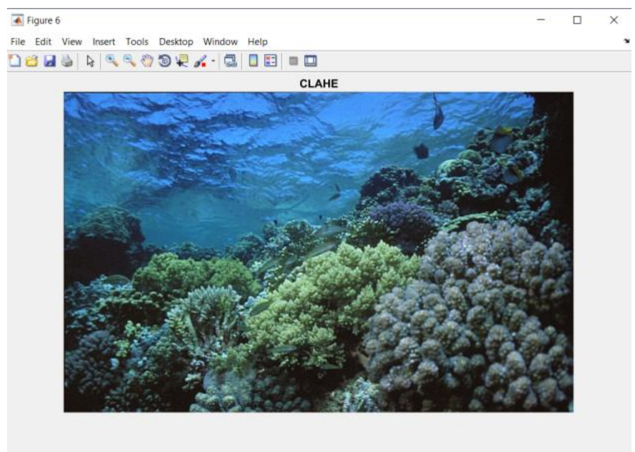


Fig. 8. CLAHE Output Image

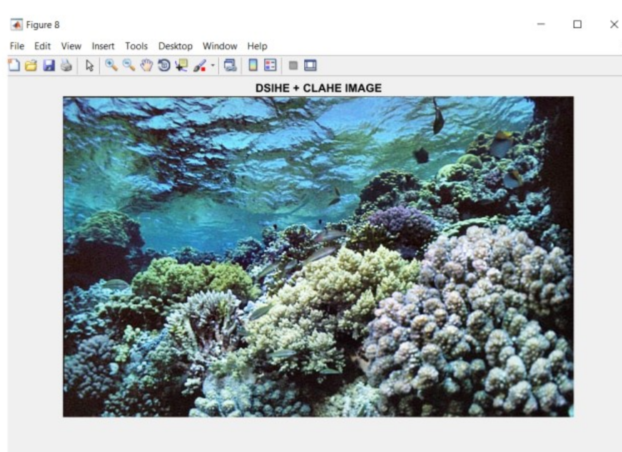


Fig. 9. CLAHE + DSIHE Output Image

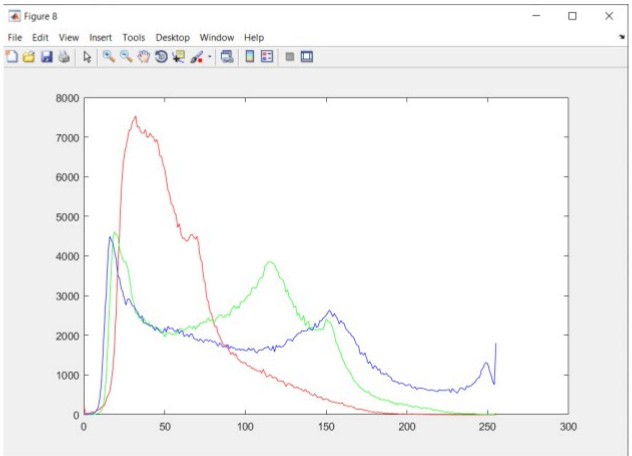


Fig. 10. Histogram of Original Image

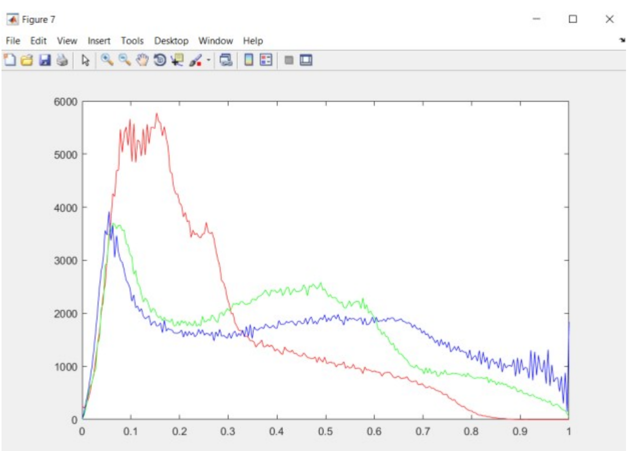


Fig. 11. Histogram of Output Image

Fig. 3 is an original image with a raw image of water. Fig. 4 is an advanced image using different color channels for color correction. Fig. 5 Total chroma image in Gamma correction. Fig. 8. CLAHE contrast-constraint adaptive histogram equalization output image. Fig. 9 This figure is a combination of CLAHE and DSIHE results. Fig.10 This represents the histogram of the original raw image of water. Fig.11 Histogram represents the graph of the output image.

The performance metrics are presented below:
Gray Value = 0.3359
Elapsed time is 7.813621
seconds. PSNR(:,:,1) =
20.9152 PSNR(:,:,2) = 21.7983
PSNR(:,:,3) = 21.1332
imagecontrast = 255

V. Conclusion

It was evaluated against the methods introduced in this study improvement methods are available using appropriate performance dimensions. Underwater Image Recovery Algorithm focus on background luminance estimation is enhanced and automatic white balance. The rear lights are extended The evaluation method aims to reduce the effect of light and white substance in water, thus increasing accuracy evaluate the backlight. In addition, an improved automatic white balance algorithm can reduce color Distortion results in clearer images with corrected colors the image is restored. This technique effectively solves problems with color appearance and contrast Existing methods such as CLAHE and DSIHE. But, There are challenges for future researchers to develop improvement methods that can be further developed and improved underwater image visibility. Recommended method This course provides a framework for further development achieve higher productivity

References

[1] Chiruvella Suresh , K. Amith Bansal, “Adaptive Contrast Enhancement and White Balancing Integration for Image Enhancement Based on Non-linear Generalized Equalization Model”, International Journal of Science and Research (IJSR), 2013.

[2] Raimondo Schettini and Silvia Corchs, “Underwater Image Processing State of the Art of Smoothing and Image Enhancement Methods”, EURASIP Journal on Advances in Signal Processing, vol. 2010, pp. 1-14, 2010.

[3] Hitam MS et al., “Mixture contrast limited adaptive histogram equaliza-tion for underwater image enhancement”, IEEE International Conference on Computer Applications Technology (ICCAT), pp. 1–5, 2013.

[4] H.R. Gordon, “Can the lambert-beer law be applied to the diffuse attenuation coefficient of ocean water” Limnology and Oceanography, vol. 34, no. 8, pp. 1389–1409, 1989.

[5] J. R. Zaneveld and W. Pegau,“Robust underwater visibility parameter,” Opt. Exp., vol. 11, no. 23, pp. 2997–3009, 2003.

[6] J. S. Jaffe,“Computer modeling and the design of optimal underwater imaging systems”, IEEE J. Ocean Eng., vol. 15, no. 2, pp. 101–111, 1990.

[7] Y. Y. Schechner and N. Karpel,“Recovery of underwater visibility and structure by polarization analysis”, IEEE J. Ocean. Eng., vol. 30, no. 3, pp. 570–587, 2005.

[8] L. Chao and M. Wang, “Removal of water scattering”,in Proc. Int. Conf. Comput. Eng. Technol., vol. 2, pp. 35–39, 2010.

[9] W. Hou et al., “Automated underwater image restoration and retrieval of related optical properties”, in Proc. IGARSS, vol. 1, pp. 1889–1892, 2007.

[10] A.Yamashita et al.,“Color registration of underwater image for under-water sensing with consideration of light attenuation”, in Proc. Int. Conf. Robot.Autom., pp. 4570– 4575, 2007.

[11] K. Iqbal et al.,“Underwater image enhancement using an integrated color model”, Int. J. Comput. Sci., vol. 34, no. 2, pp. 2–12, 2007.

[12] I. Vasilescu et al.,“Color-accurate underwater imaging using perceptual adaptive illumination,” in Proc. Robot. Sci. Syst., 2010.

[13] Sandbhor et al., International Journal of Advanced Research in Computer Science and Software Engineering, vol.5, no. 5.

[14] Zhang, Kai, et al. “Beyond a Gaussian denoiser: Residual learning of deep cnn for image denoising.” IEEE transactions on image processing 26.7 (2017): 3142-3155.

[15] S. L. Lee and C. C. Tseng, “Color image enhancement using histogram equalization method without changing hue and saturation”, IEEE International Conference on Consumer El., pp. 676- 680, IJARCSSE, 2017.

[16] Iqbal K et al., “Enhancing the low quality images using unsupervised colour correction metho”, IEEE Int. Conf. Syst. Man Cybern. (SMC), pp 1703–1709, 2010.

[17] Singhai J. and Rawat P., “Image enhancement method for underwater, ground and satellite images using brightness preserving histogram equal-ization with maximum entropy”, International Conference on Conference on Computational Intelligence and Multimedia Applications, vol. 3, pp.507–512.

[18] Yeong-Taeg Kim, “Contrast enhancement using brightness preserving Bi-Histogram equalization”, IEEE Trans. Consumer Electronics, vol.43, no.1, pp. 1-8, 1997.

[19] Wang et al., “Image enhancement based on equal area dualistic sub-image histogram equalization method”, IEEE Trans. on Consumer Elec-tronics, vol. 45, no.1, 68-75, 1999.

[20] Yeong-Taeg Kim, “Contrast enhancement using brightness preserving Bi-Histogram equalization”, IEEE Trans. Consumer Electronics, vol.43, no.1, pp.1-8, 1997.

[21] Sukhjinder Singh et al., "Comparative Study and Implementation of Image Processing Techniques Using MATLAB", International Journal of Advanced Research in Computer Science and Software Engineering, vol.2, no.3, pp. 244-250, 2012.

[22] C.Sasi varnan et al., "Image Quality Assessment Techniques pn Spatial Domain", International Journal of Computer Science and Technology, vol. 2, no.3, pp. 177-184, 2011.

[23] Anish Kumar Vishwakarma and Agya Mishra, "Color Image Enhance-ment Techniques: A Critical Review", Indian Journal of Computer Sci-ence and Engineering, vol. 3 no. 1, pp. 39-45, 2012.

[24] Rafael C. Gonzalez, Richard E. Woods, "Digital Image Processing," 3rd Edition, Prentice Hall; ISBN: 013168728X; August 2007.