© August 2024| IJIRT | Volume 11 Issue 3 | ISSN: 2349-6002

Histogram Based Underwater Image Enhancement

Aaliya Shaikh[1], Dhruv Dolas[2], Arohi Rathod[3], Aditya Kuleyar[4]
[1,2,3,4]*Department of Electronics and Telecommunications Symbiosis Institute of Technology*, Pune, India
20070123084

***Abstract*—Underwater imaging encounter various challenges due to inherent characteristic of the aquatic nature, such as scattering of light, colour distortion, attenuation, or low illumination. Hence, the quality of image is often degraded by these factors, limiting their usage in various fields like marine biology or underwater archaeology. To overcome such problem, Under- water Image Enhancement is done. The technique aims towards resolving these challenges and improving quality of underwater images. This paper explores the approach of histogram-based techniques to enhance the quality of underwater images and extract maximum hidden information. The technique offers an adaptable and effective method for image enhancement and detail extraction.**

***Index Terms*—Underwater Images, histogram-based techniques, information extraction, enhancement**

I. INTRODUCTION

The paper focuses on underwater image enhancement using histogram-based techniques. The underwater images face challenges related to visibility due to turbid characteristic of water. Image has two components, energy and reflectance. Energy being the low frequency component, it is affected my depth of the water and scattering of light causing low frequency energy variation in the image. Histogram techniques can help improve the visibility by enhancing the contrast of the high frequency reflectance component. In the aquatic environment, algae and phytoplankton can cause suspended particles in the water and a blue or greenish effect. Hence, valuable information is lost or is not clearly visible. Therefore, adaptive histogram equalization (AHE) and matching, and linear histogram manipulation techniques are used. The pro- posed approach uses adaptive histogram equalization (AHE) technique, which helps in improving contrast and visibility of images. AHE adjusts an image's histogram to improve the distribution of pixel intensities. This reduces the low visibility and colour deterioration of the degraded image. The method of linear histogram manipulation involves adjustments in the pixel intensities linearly to stretch the range of the image and obtaining any hidden information due to underwater characteristics. Linear histogram operations allow adjustments in brightness and contrast of image and manipulating them according to requirements. The technique is useful when dealing with large datasets.

II. LITERATURE SURVEY

The article" An Underwater Image Enhancement Bench- mark Dataset and Beyond" by Chongyi Li et al. suggests a new benchmark dataset for underwater image enhancement and assesses several cuttingedge techniques on the dataset. The dataset includes 950 actual underwater photographs, 890 of which have corresponding reference photographs. The reference photos, which were taken in crystal-clear water, depict the same scene as the underwater photos. On the dataset, the authors assessed a number of cutting-edge underwater image enhancement techniques. They discovered that deep learning-based methods were the ones that worked the best. Deep learning techniques can produce cutting-edge outcomes by learning intricate features from underwater images. The authors also suggested a fresh approach to underwater im- age enhancement called Water-Net. A deep learning-based approach called Water-Net can produce cutting-edge outcomes on the benchmark dataset.

Images of the underwater world are frequently hazy and fuzzy because of the way water molecules scatter light. As a result, it may be difficult to distinguish objects in underwater images, which may limit their applicability for activities like marine biology research and underwater exploration. Researchers have created a number of methods to improve the visibility and restore underwater images. Assessing the efficacy of these techniques can be difficult, though, because there isn't a common dataset of underwater images with a known ground truth. The study by Duarte et al. suggests a brand-new dataset of underwater pictures with known turbidity levels. This dataset can be used to fairly and impartially assess how well underwater image restoration techniques perform. On their dataset, the authors tested a number of well-known underwater image restoration techniques. They discovered that some techniques outperformed others at various levels of degradation. The development of new and better underwater image restoration techniques can be guided by the information provided here. Researchers who are creating and analyzing underwater image restoration techniques can benefit greatly from the dataset proposed by Duarte et al. Anyone interested in learning more about underwater image processing and restoration can also benefit from it.

Low contrast, colour distortion, and noise are common in underwater images. It is difficult to see what is in the image as a result. In this paper, the authors present a novel colour correction, contrast enhancement, and saliency detection approach for underwater image enhancement. The steps in the suggested procedure are as follows: Colour correction: The hazy input image is converted to the YCbCr colour space. Adaptive histogram equalization (AHE) is then used to process the Y channel in order to correct the image's colour. Enhancing contrast: The contrast of the image is improved by processing the Y channel with gamma correction. Weight map creation: Two weight maps are created, one for the contrast-enhanced image and one for the colour-corrected image. The weight maps are used to prioritize particular areas of the image, such as those that contain the most significant features. A saliency detection algorithm is used to create the weight maps. Their approach begins by using an approach called adaptive histogram equalization to correct the image's colour. Then, it uses a process known as gamma correction to improve the image's contrast. Finally, it employs a saliency detection algorithm to pinpoint the image's key elements. When the image is combined, these features are then given more weight. On a dataset of murky underwater images, the authors tested their method and demonstrated that it outperformed other cutting-edge approaches in terms of contrast enhancement, colour correction, and overall image quality. The proposed fusion-based approach, according to the authors, is an easy and efficient way to improve the visibility of murky underwater images. In terms of contrast amplification, colour adjustment, and overall image quality, it performs better than other cutting- edge techniques.

Due to the water's ability to scatter and absorb light, underwater images are frequently challenging to see. This study by Xiangyu Deng et al. suggests a brand-new technique for dehazing and enhancing underwater images by first removing the colour of the light source from the images. The method begins by estimating the colour of the light source in the image. By analysing the hue channel of the image using a statistical method, this is accomplished. The estimated colour of the light source is then taken out of the picture. Next, a transmission map is used to perform the dehazing step. By combining the dark channel prior and the scene depth, the transmission map is estimated. The image is dehazed using the transmission map after it has been estimated. It was demon- strated that the suggested method for improving underwater images outperformed other cutting-edge techniques. This study may contribute to enhancing the visibility of underwater images for a variety of applications, including underwater photography, marine biology, and underwater surveillance.

The authors of a study titled "Mixture contrast limited adaptive histogram equalization for underwater image enhancement" are Muhammad Suzuri Hitam and colleagues. The new technique for underwater image enhancement that is suggested in this paper combines histogram equalization (HE) and con- trast limited adaptive histogram equalization (CLAHE). Light is scattered and absorbed by the water, making it frequently challenging to see underwater images. By dividing the image into small blocks and then equating the histogram of each block, the "CLAHE" technique improves the contrast in an image. By balancing the image's overall histogram, the" HE" technique improves the contrast in an image. The suggested method is a rapid and effective means of enhancing underwater image quality. The combination of the well-known CLAHE and HE techniques forms the foundation of this method. The method is straightforward to use and can be used to enhance underwater images with various haze levels. The performance of the suggested technique for enhancing underwater images has been shown to be superior to any other state-of-the-art techniques.

Researchers Weilin Luo, Shunqiang Duan, and Jiwen Zheng from Fuzhou University in China have created a novel method to enhance underwater images in their study," Underwater Image Restoration and Enhancement Based on a Fusion Algorithm with Colour Balance, Contrast Optimization, and Histogram Stretching." Their approach combines several essential techniques, such as histogram stretching, contrast amplification, and colour balance. By utilizing these procedures, the team successfully combats the issues associated with underwater image degradation, producing underwater images that are clearer, more vibrant, and visually appealing. Diverse fields, including marine biology, underwater archaeology, and underwater surveillance, where high-quality imagery is essential for analysis and decision-making, could greatly benefit from this research.

Researchers Qianqian Xue, Hongping Hu, Yanping Bai, Rong Cheng, Peng Wang, and Na Song suggest a technique to enhance underwater image quality. The algorithm aims to correct the flaws typically found in underwater photography, ultimately producing clearer and more aesthetically pleasing images by addressing colour distortions and enhancing contrast. This research is useful for a variety of situations where clear image capture is crucial for accurate analysis and decision-making, such as underwater surveillance and environmental monitoring.

III. METHODOLOGY

Enhancement of underwater images requires appropriate algorithm and precision. The first step was to collect the suitable dataset. The dataset used is taken from Turbid Dataset. It consists of turbid(Fig 1), milky (Fig 2), greenish and blue images (Fig 3) with different levels of degradation and a reference image for each kind.

At the start, the approach was to compare the histogram of enhanced version of original image to the reference image. Here, the histogram of reference image(Fig 4) had better and even distribution of intensity values whereas histogram of the enhanced image had lower range intensity values(Fig 5) with most of the values distributed in the middle of the histogram.

Fig. 1. Turbid images

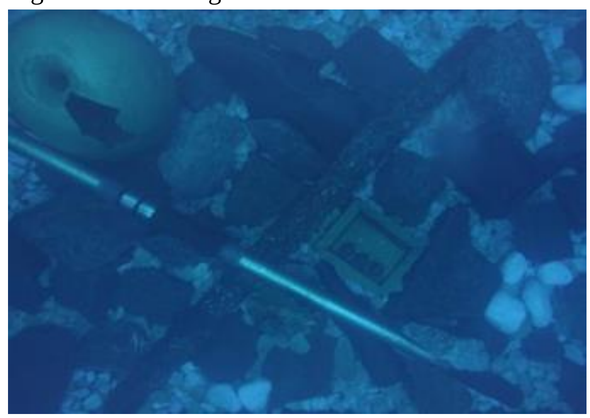

Fig. 2. Deep blue Images

To overcome this problem some other histogram based techniques were used. The linear contrast stretching and linear histogram matching using lookup table was implemented on the dataset to obtain required results. First both the techniques are individually implemented starting with contrast stretching and then histogram matching. Both the techniques are implemented as a single algorithm for optimum results.

Contrast stretching is a technique used to improve visibility of features in an image by expanding the range of pixel intensity values. This is used to linearly stretch the intensity

Fig. 3. Milky

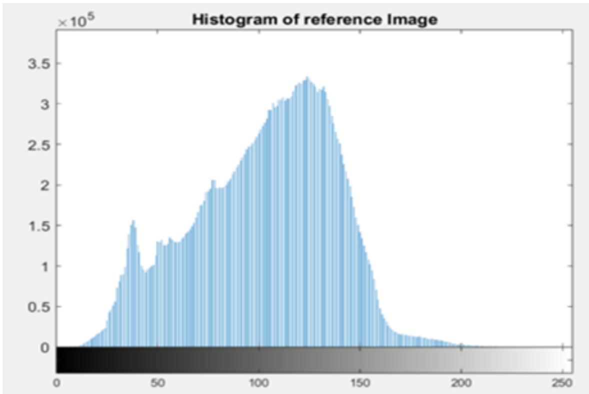

Fig. 4. Histogram of the Reference Image

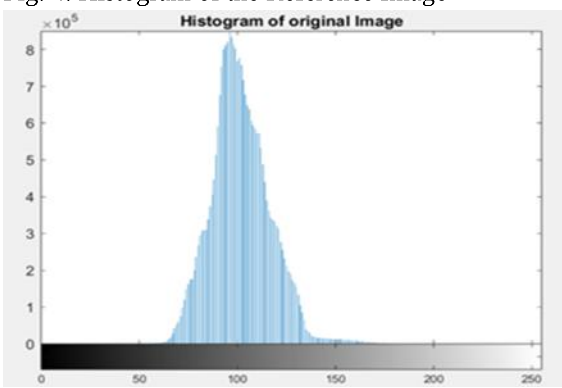

Fig. 5. Histogram of the Original Image

levels of the image to occupy the full available range. Contrast stretching increases the amount of contrast between various parts of an image by making the darker areas darker and the brighter areas brighter. Usually, linear pixel intensity modifications are used for contrast stretching. The approach looks like applying a linear mapping function to the initial values of the pixels.

Stretching Formula:

$$S' = \frac{S_{max}-S_{min}}{L_{max}-L_{min}}(L - L_{min}) + S_{min} \qquad (1)$$

Where, L is original pixel intensity value. S' is the contrast- stretched pixel value based on the original pixel value L. Smax and Smin are maximum and minimum pixel values of original image. Lmax and Lmin are maximum and minimum allowable pixel values after contrast stretching.

Based on the original pixel value L and the minimum and maximum values in both the original and stretched ranges, the formula calculates the contrast-stretched pixel value S. This formula is used to extend the original image's pixel values to a new range that is defined by Lmax and Lmin. Utilizing the entire dynamic range of pixel intensities performs to improve contrast.

We initially used adaptive histogram technique, which enhances the constrast of the individual pixels, however, the resulting histogram is distorted.(fig 6)

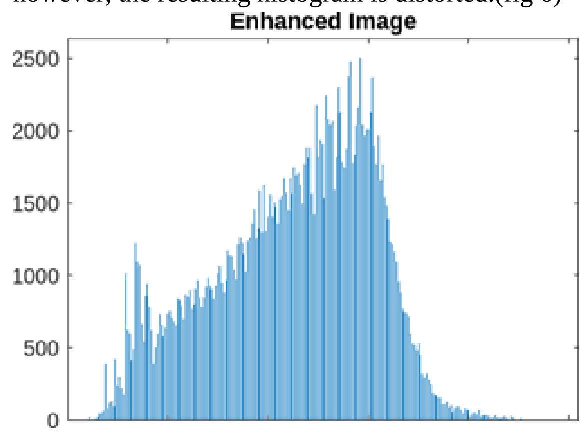

Fig. 6. resultant image histogram from adaptive technique

The technique of histogram matching modifies the intensity distribution of an input image to match a specified reference image. The algorithm transforms the pixel values of the input image in a way that histogram of input image closely matches the histogram of reference image. This technique uses lookup table that maps the original pixel intensities to their corresponding transformed value. This process involves generation of cumulative distribution function (CDF) for both input as well as reference image. Then normalizing CDF values to define a dedicated range. Based on the CDF values a lookup table is constructed. The lookup table is used to swap out the original intensity value for each pixel in the input image with the corresponding transformed intensity. By doing this, the pixel values are effectively remapped to match the desired distribution. Though this is a quite effective technique, it doesn't directly work on blue images. To make this technique work, we need to apply it on all three bands RGB to obtain required results.

To justify our different algorithms applied, a survey was conducted. The survey consisted of four different algorithms applied over a single image and people from different aca- demic background were asked to choose one image out of four that according to them gave most information. Four such underwater images were used for this survey.

IV. IMPLEMENTATION AND RESULTS

The algorithm used for histogram equalization is applied on degraded and the reference image. The difference in histogram can be clearly seen when mapped together. We have tried matching both histograms so that range of the pixel intensity values of degraded image and the reference image match a particular range of pixels to get the enhanced image. But this algorithm does not give precision in results because the shape of histogram changes. This algorithm only works on turbid and milky images (fig 7)

When applying linear contrast stretching, we get enhanced image with high intensity values(fig 8). To obtain better enhanced version of the image we lowered the intensity values of the image (fig 9).

To address the problem of higher intensity images, linear contrast stretching using formula (equation 1). This algorithm doesn't require lowering of intensity values. The direct application of the algorithm gives appropriate results. Along with

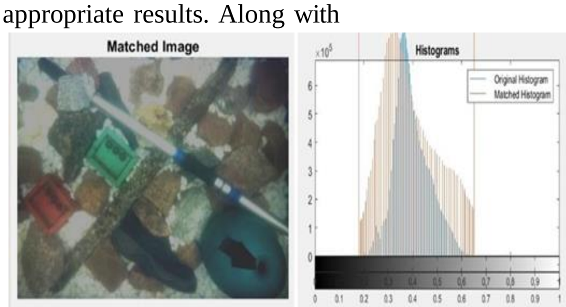

Fig. 7. results from equalization technique

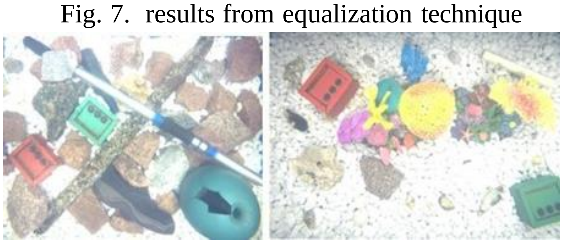

Fig. 8. results from Contrast Stretching technique

this we added histogram mapping to the algorithm for better precision (fig 10)

Contrast stretching and histogram matching combined also doesn't directly work on blue images. Hence, we need to separate three bands (RGB), apply histogram matching and contrast stretching algorithm and then combine all the three bands (RGB) back together.

By using this algorithm, we have conducted a survey to see how accurate it is and what are the users' preferences on this. The questionnaire involved individuals from various fields of study in order to arrive at neutral results.

The vast majority of the surveys were in favour of the Adaptive Histogram Algorithm (AHA). The reason why this algorithm became popular was because it could improve im- ages contrast by incorporating a component that adapted local image variation. The reason for that was its successfulness in different situations and as such considered it an easy option for several image processing assignments.

Aside from most respondents who preferred the Adaptive Histogram Algorithm, a significant group of participants indicated that they would prefer using a mixture of methods. In particular, a quite small proportion of respondents considered development to include intensifying of intensity, linear contrast

Fig. 9. results from Contrast Stretching technique after intensity reduction

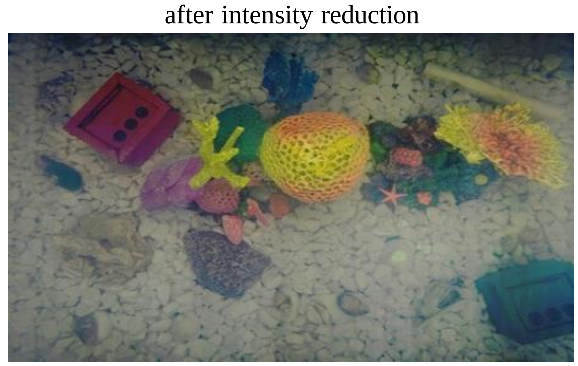

Fig. 10. results from Contrast Stretching technique along with histogram match

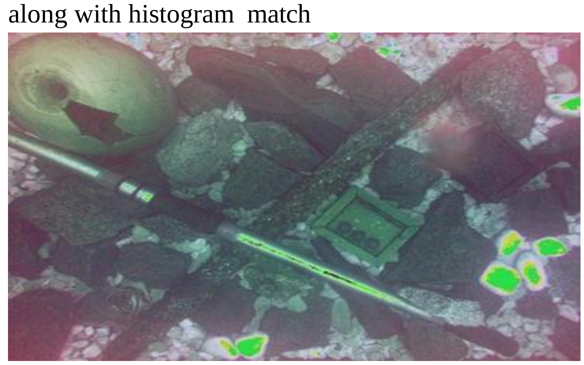

Fig. 11. results from Contrast Stretching technique along with histogram match and band separation

enhancement, and histogram mapping. The wide acceptance of this technique could be derived from the fact that it offers a one-stop solution to image improvement; that is, handling both global and local contrast concerns.

However, a minority of respondents advocated for independent contrast enhancing, thus an honorable mention should be made in regard to this technique. For some, this was easy and quick means of enhancing image appearance, viewership and general visual quality.

Our survey uncovers an important fact about how many people's choices differ in regard to other means of effectuating image improvements. Thus, it is clearly evident that there's demand for various set of approaches depending on the context. The Adaptive Histogram Algorithm is widely accepted as the leader in image enhancement, but it must also be emphasized that there is no one-size-fits-all approach.

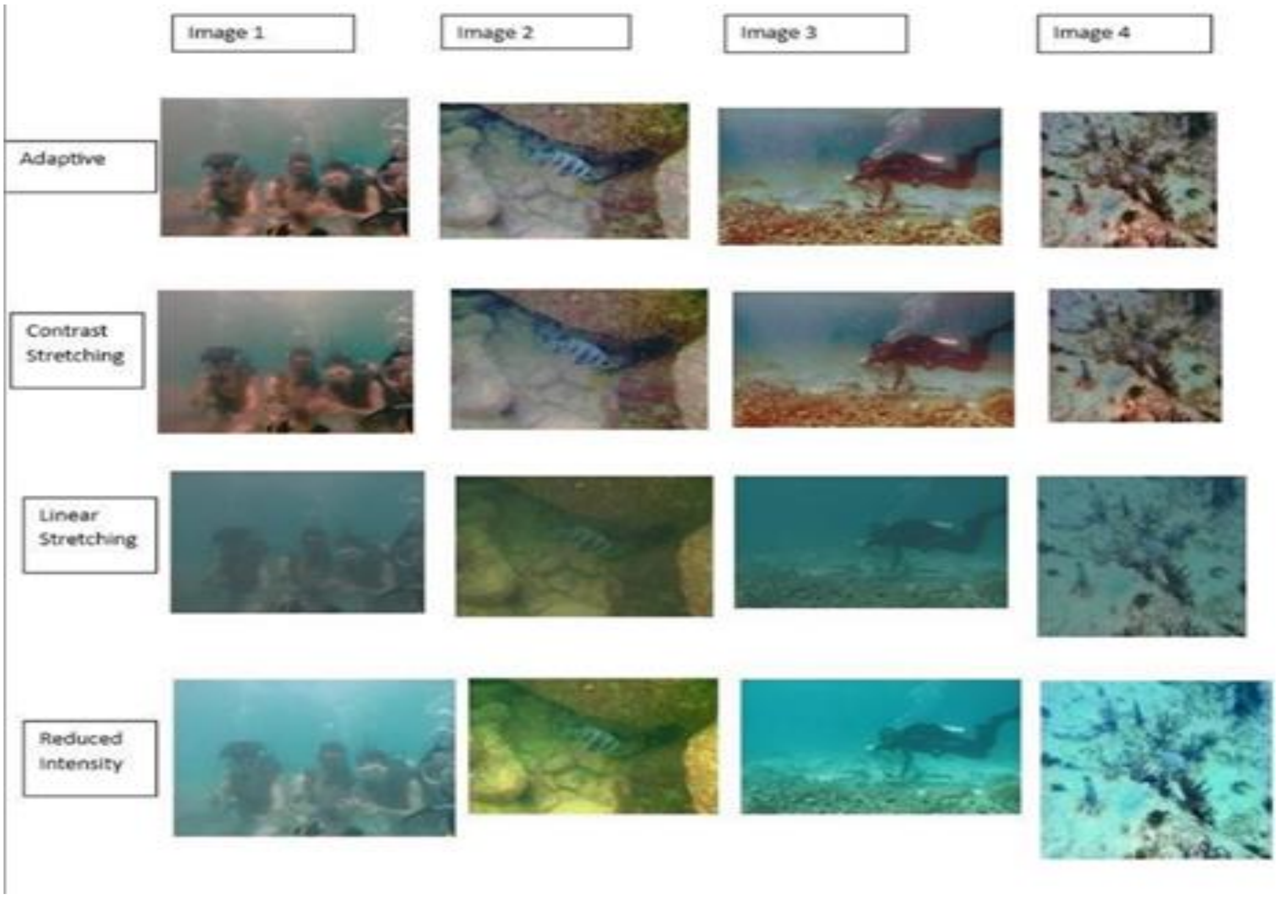

Fig. 12. Images and techniques used in Survey.

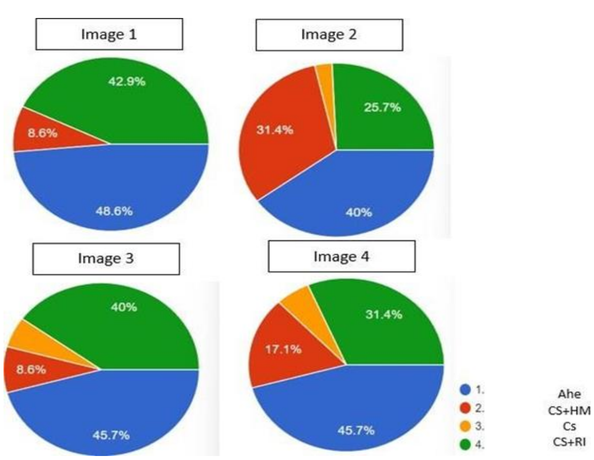

Fig. 13. results from survey

V. CONCLUSION

The most significant challenges faced during underwater image enhancement includes, light scattering, color distortion, and low illumination are discussed in this paper. These aspects frequently result in low image quality, restricting use of underwater images in various fields. The paper suggests using histogram-based techniques for extracting hidden information in distorted images. The method of adaptive histogram equalization (AHE) performs efficiently in enhancing the histogram of the image to improve the distribution of pixel intensities, which increases contrast and visibility. Also, linear adjustments to pixel intensities used in linear histogram manipulation stretches the image range and finds hidden information that is specific to underwater characteristics. The paper illustrates the use of contrast stretching and histogram matching. The formula used for contrast stretching utilizes the entire dynamic range of pixel intensities. On the other hand, histogram matching adjusts the input image's range of intensity to closely match the reference image. This method effectively converts pixel values to create the desired distribution of intensities by mapping original pixel intensities to their corresponding transformed values using a lookup table. The survey conducted to validate the algorithms, gave a new lookout towards the project. In conclusion, the adaptive histogram based methods for underwater image enhancement give a flexible and efficient approach.

REFERENCE

[1] Schettini, R., Corchs, S," Underwater Image Processing: State of the Art of Restoration and Image Enhancement Methods". EURASIP J. Adv. Signal Process. 2010, 746052 (2010).

[2] Wan M, Gu G, Qian W, Ren K, Chen Q, Maldague X,"Infrared Image Enhancement Using Adaptive Histogram Partition and Brightness Correction".Remote Sensing,2018.

[3] Chongyi Li, Chunle Guo, Wenqi Ren, Runmin Cong, Junhui Hou, M Sam Kwong, and Dacheng Tao," An Underwater Image Enhancement Benchmark Dataset and Beyond". IEEE TRANSACTIONS ON IMAGE PROCESSING, November, 2019

[4] A. Duarte, F. Codevilla, J. D. O. Gaya and S. S. C. Botelho, "A dataset to evaluate underwater image restoration methods". OCEANS 2016 - Shanghai, Shanghai, China, 2016

[5] R. Singh and M. Biswas, "Adaptive histogram equalization based fusion technique for hazy underwater image enhancement" .2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Chennai, India, 2016.

[6] X. Deng, H. Wang and X. Liu, "Underwater Image Enhancement Based on Removing Light Source Color and Dehazing". in IEEE Access, vol. 7, pp. 114297-114309, 2019.

[7] M. S. Hitam, E. A. Awalludin, W. N. Jawahir Hj Wan Yussof and Z. Bachok, "Mixture contrast limited adaptive histogram equalization for underwater image enhancement". 2013 International Conference on Computer Applications Technology (ICCAT), Sousse, Tunisia, 2013.

[8] Qianqian Xue, Hongping Hu, Yanping Bai, Rong Cheng, Peng Wang and Na Son, "Underwater image enhancement algorithm based on colour correction and contrast enhancement". Vis Comput,2023. https://doi.org/10.1007/s00371-023-03117-0

[9] W. Luo, S. Duan and J. Zheng, "Underwater Image Restoration and En hancement Based on a Fusion Algorithm With Color Balance, Contrast Optimization, and Histogram Stretching". in IEEE Access, vol. 9, pp. 31792-31804, 2021.

[10] S. Anwar and C. Li, " Diving deeper into underwater image enhance ment: A survey". arXiv preprint arXiv: 1907.07863, 2019.

[11] C. Li, J. Guo, and C. Guo, "Emerging from water: Underwater image color correction based on weakly supervised colro transfer". IEEE Signal Process. Lett., vol. 25, no. 3, pp. 323-327, 2018.

[12] C. Li, J. Guo, and C. Guo, "Emerging from water: Underwater image color correction based on weakly supervised colro transfer". IEEE Signal Process. Lett., vol. 25, no. 3, pp. 323-327, 2018.

[13] N. Hautiere, J. Tarel, D. Aubert, et al., "Blind contrast enhancement assessment by gradient ratioing at visible edges". Image Anal. Stereo., vol. 27, no. 2, pp. 87-95, 2011.

[14] T. Aydin, R. Mantiuk, K. Myszkowski, et al., "Dynamic range indepen detn image quality assessment". ACM Trans. Graphics, vol. 27, no. 3,pp. 69-79, 2008.

[15] M. Yang and A. Sowmya, "An underwater color image quality evaluation metric". IEEE Trans. Image Process., vol. 24, no. 12, pp. 6062-6071, 2015.

[16] K. Panetta, C. Gao, and S. Agaian, "Human-visual-system-inspired underwater image quality measures". IEEE J. Ocean Eng., vol. 41, no.3, pp. 541-551, 2016.

[17] J. Xiao, J. Hays, K. Ehinger, et al., "Sun database: Large-scale scene recgonition from abbey to zoo". in Proc. of IEEE Int. Conf. Comput. Vis. Pattern Rec. (CVPR), 2010.

[18] D. Berman, D. Levy, S. Avidan, et al., "Underwater single image color restoration using haze-lines and a new quantitative dataset". arXiv

preprint arXiv:1811.01343, 2018.
[19] A. Duarte, F. Codevilla, J. Gaya, et al., "A dataset to evaluate underwater.