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Enhancement of Underwater Image Restoration based on Multi Thresholding Algorithm

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ABSTRACT

Underwater imaging is a challenging task due to the presence of various optical distortions, such as scattering, absorption, and color cast. This paper presents an approach for enhancing underwater images using a multi-thresholding algorithm in MATLAB 2013a Version. The proposed method includes several key steps, including input image preprocessing, adaptive histogram analysis, R-plane and B-plane separation, multi-threshold algorithm, pixel averaging, normalization, and reconstruction. Initially, the input image undergoes preprocessing to remove noise and enhance contrast. Adaptive histogram analysis is then performed to adjust the image's dynamic range and enhance the visibility of details. R-plane and B-plane separation is utilized to separate the color channels and isolate the red and blue components, which are most affected by underwater distortions.

Next, a multi-thresholding algorithm is employed to segment the image into different regions based on intensity levels. This step aims to identify the underwater regions and the non-underwater regions accurately. Afterward, pixel averaging is applied to the underwater regions to reduce noise and improve image quality. Normalization is performed to enhance the visibility of details in the restored image by stretching the intensity values across the entire dynamic range. Finally, the restored image is reconstructed by combining the enhanced underwater regions with the non-underwater regions. To evaluate the performance of the proposed method, several comparative parameters are used, including Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), and S-Index. These parameters provide quantitative measures of image quality, sharpness, and similarity to the ground truth. The experimental results demonstrate that the proposed approach effectively restores underwater images, significantly reducing the impact of optical distortions. The comparative analysis shows improved image quality, with higher PSNR values, lower

MSE values, and enhanced S-Index scores when compared to other existing methods. The implementation of the proposed approach in MATLAB 2013a Version provides an efficient and accessible solution for underwater image restoration.

Keywords : Pre-processing, Adaptive Histogram analysis, MATLAB 2013a Version, R-Plane, B-Plane Separation, Multithreshold Algorithm, Pixel Averaging

I. INTRODUCTION

Underwater imaging is a challenging task due to the presence of various optical distortions that degrade the quality of captured images. These distortions include scattering, absorption, and color cast, which result in reduced visibility and loss of details. Therefore, the restoration of underwater images has become a crucial area of research with applications in marine biology, underwater surveillance, and underwater exploration.

This paper proposes an approach for enhancing underwater image restoration using a multi-thresholding algorithm implemented in MATLAB 2013a Version. The goal is to mitigate the optical distortions and improve the overall quality and visibility of underwater images.

The proposed method consists of several key steps that collectively address the challenges associated with underwater imaging. The initial step involves preprocessing the input image, which aims to remove noise and enhance the image's contrast. By reducing noise and enhancing contrast, the subsequent restoration steps can be performed more effectively.

Adaptive histogram analysis is then applied to adjust the dynamic range of the image. This technique enhances the visibility of details in the image by stretching the intensity values across a wider range. By increasing the dynamic range, the restored image can exhibit improved contrast and enhanced visibility of underwater objects.

To further address the color distortions in underwater images, the R-plane and B-plane separation technique is utilized. This separation isolates the red and blue color channels, which are most affected by underwater distortions. By treating these channels separately, it becomes possible to apply targeted restoration techniques and improve the color fidelity of the image.

The multi-thresholding algorithm is employed to segment the image into different regions based on intensity levels. This step is crucial for accurately identifying the underwater regions and distinguishing them from non-underwater regions. By effectively identifying and isolating the underwater regions, subsequent restoration techniques can be applied specifically to these areas, further enhancing their quality.

Pixel averaging is then utilized to reduce noise in the identified underwater regions. By averaging the pixel values in these regions, noise is attenuated, leading to improved image quality and enhanced visibility of underwater objects.

Normalization is applied to enhance the visibility of details by stretching the intensity values across the entire dynamic range. This technique ensures that the restored image utilizes the full available range of intensity values, resulting in better contrast and improved visualization of underwater details.

Finally, the restored image is reconstructed by combining the enhanced underwater regions with the non-underwater regions. This integration ensures that the overall image maintains a natural and coherent appearance, with restored underwater regions seamlessly blending with the rest of the image.

To evaluate the performance of the proposed method, several comparative parameters are utilized, including Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), and S-Index. These parameters provide objective measures of image quality, sharpness, and similarity to the ground truth [1]. By comparing the results of the proposed method with existing techniques, the effectiveness and superiority of the proposed approach can be demonstrated.

The implementation of the proposed approach in MATLAB 2013a Version provides a practical and accessible solution for underwater image restoration. MATLAB's computational capabilities and extensive image processing toolbox make it suitable for implementing the complex algorithms involved in underwater image restoration. The results obtained from the proposed method can contribute to advancements in underwater imaging and facilitate improved analysis and interpretation of underwater scenes.

The organizational framework of this study divides the research work in the different sections. The literature review is presented in section 2. Further, in section 3, fundamentals of underwater imaging was discussed. Moreover, in next section IV and V, briefly explain about Existing System and Proposed System and finally the Simulation results discussed in section VI. Conclusion and future work are presented by last sections VII.

II. LITERATURE SURVEY

In this subsection we are going to discuss about the works which are already carried out by the scientists or research scholars in the field of the underwater-image reconstruction.

In this paper [2], the nonlinear approximation of the reconstruction of images is explained by using the Huygens Fresnel diffraction patterns, here again the SAR images is used as a target images which can be used to make up a knowledge of a hologram for all the frequencies and angles to inspect target.

In this paper [3], describes about a method of recording by combining back-illumination of the in-line objects with an off-axis reference beam which produces the low-aberration holograms. The experiments conducted in their paper concluded by saying that the use of off-axis scheme with the normal incidence of the object beam on the holoplates which can provide the reduction of the aberrations without any additional compensation at the reconstruction stage.

In this paper [4], Reconstruction of an underwater object from a sequence of the images distorted by moving the water waves is a challenging task. Here they use the bi spectrum technique to analyse the raw images in a sequences and recover the phase information of the true object. The limitations of the paper consists of, it doesn’t support on large computer memory and high computation (if dimension of image >3).

In this paper [5], presents the three dimensional vision techniques in the field of the computer vision aims mainly for the reconstructing a scene which finds its three dimensional geometrical information. the scene of the geometry and the pose of the camera are unknown with the problem to be addresses is very close to the problem of the computer vision and in the computer vision namely SFM (structure from Motion). The reconstruction method developed in this paper is very well extended for further to the segment of the top of the surfaces of the cuboid shaped objects which are considered as the interest at which the objects can be reconstructed using some of the reconstruction process.

III.FUNDAMENTALS OF UNDERWATER IMAGING

The propagation of light differs in water and air. In the light propagation in water, there are several important factors that result in attenuation and scattering of light. The density of water is greater than air, which causes the attenuation of light. Water selectively scatters and absorbs certain wavelengths of visible light. Suspended particles in water affect the light transmission and produce scattering of light. Various types of noise occur for example marine snow that causes additional light backscattering. Temperature and salinity also cause the light scattering. To summarize, the light attenuation and scattering are more serious in water than air. As a result, underwater optical images are apt to blur along with lower contrast. The light received by an underwater camera can be divided into three components: direct component, forward scattered component and backward scattered component. The total light intensity received by the camera sensor can be expressed as:

$$E_T = E_d + E_f + E_b, \qquad (1)$$

where ET represents the total light intensity; Ed the direct component; Ef the forward scattered component; Eb the backward scattered component. The three components can be calculated as follows. For direct component, it can be calculated as:

$$E_d = Je^{-cd}, \qquad (2)$$

where J is the reflection part from the object after receiving light from an illumination source; c is the attenuation coefficient; d is the distance between the object and the sensor. For forward scattered component, it is given by

$$E_f = E_d * g = Jt * g, \qquad (3)$$

where g is the point spread function (PSF) for predicting beam propagation and imaging system performance [45], [46]. t is defined as t = e −cd . As can be seen from Eq.(3), the forward scattered component Ef is the convolution of the direct component and PSF. For backward scattered component, it can be expressed as:

$$E_b = B_\infty(1 - t), \qquad (4)$$

where g is the point spread function (PSF) for predicting beam propagation and imaging system performance [45], [46]. t is defined as t = e −cd . As can be seen from Eq.(3), the forward scattered component Ef is the convolution of the direct component and PSF. For backward scattered component, it can be expressed as:

$$E_T = Jt + B_\infty(1 - t). \qquad (5)$$

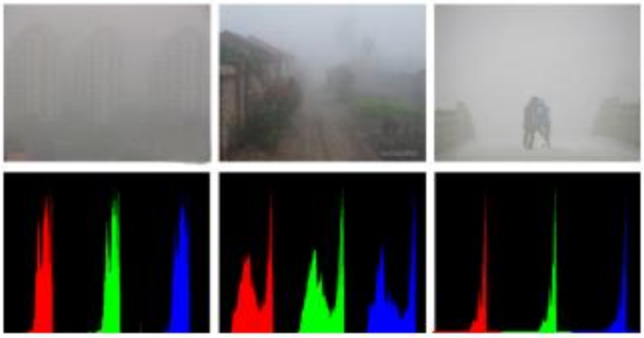


Figure 1: Foggy images and histograms.

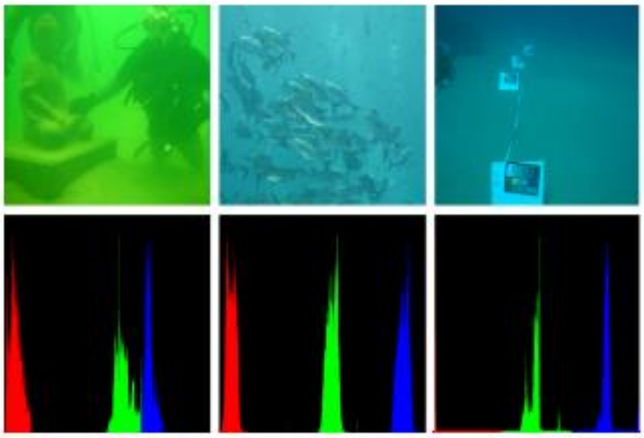


Figure 2: Underwater images and histograms

IV. EXISTING SYSTEM

Underwater images suffer from various distortions such as scattering, absorption, and color cast, which significantly degrade their quality and visibility. The restoration of underwater images plays a crucial role in improving their visual appearance and facilitating better analysis. This paper presents an approach for underwater image restoration using pre-processing, feature extraction, color balance, contrast enhancement, histogram stretching, and implementation in MATLAB 2013a Version.

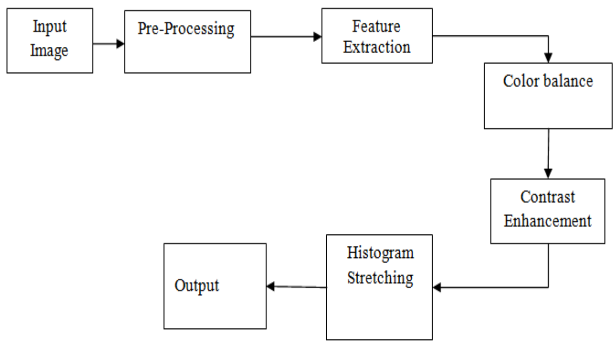


Figure 1: Existing System Block Diagram

1. Pre-processing: The pre-processing step aims to remove noise and enhance the overall quality of the input underwater image. Common techniques such as noise reduction filters, such as median or Gaussian filters, are applied to reduce noise and improve the clarity of the image.
2. Feature Extraction: Feature extraction techniques are employed to identify and extract relevant information from the underwater image. This step helps to capture the unique characteristics of the image, which can be utilized for subsequent restoration processes.
3. Color Balance: Color balance techniques are applied to correct the color cast caused by water absorption and scattering. By adjusting the color channels, the image can regain a more natural and balanced color appearance. Color correction algorithms, such as gray-world or white balance methods, can be utilized for this purpose.
4. Contrast Enhancement: Contrast enhancement techniques are employed to improve the visibility of details in the restored underwater image. By increasing the contrast, the image can exhibit better differentiation between different objects and regions. Algorithms such as histogram equalization or contrast stretching are commonly used for this purpose.
5. Histogram Stretching: Histogram stretching is applied to expand the dynamic range of the image's intensity values. By redistributing the pixel intensities, the image can have enhanced brightness and contrast. This step is particularly useful for bringing out details in darker regions or regions affected by low lighting conditions.
6. Output: The restored underwater image is generated as the final output of the restoration process. It represents an enhanced version of the original input image, with improved visibility, color balance, and contrast. The output image can be further analyzed or used for various applications such as scientific research, marine biology, or underwater surveillance.

V. PROPOSED SYSTEM

Underwater image restoration aims to improve the quality and visibility of images captured underwater, which are often affected by various optical distortions. This overview presents an approach for underwater image restoration using a multi-thresholding algorithm in MATLAB 2013a Version. The proposed method involves several stages, including input image pre-processing, adaptive histogram analysis, R-plane and B-plane separation, multi-threshold algorithm, pixel averaging, normalization, reconstruction, and evaluation using comparative parameters such as PSNR, MSE, S-Index.

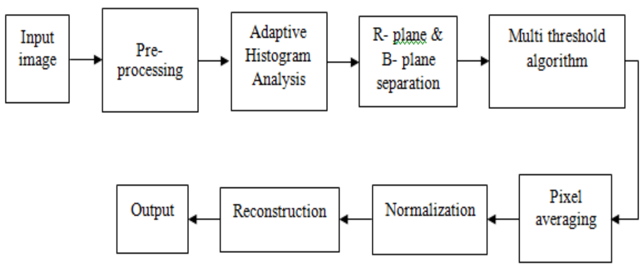


Figure 2: Proposed System Block Diagram

A. METHODOLOGY

1. Input Image: The methodology starts with an input underwater image that has been affected by optical distortions such as scattering, absorption, and color cast.
2. Preprocessing: The input image undergoes preprocessing to remove noise and enhance its quality. Common preprocessing techniques include noise reduction filters, such as median or Gaussian filters, to reduce noise and improve image clarity.
3. Adaptive Histogram Analysis: Adaptive histogram analysis is performed to adjust the dynamic range of the image. This step enhances the visibility of details by stretching the intensity values across a wider range. It can be achieved using algorithms like adaptive histogram equalization or contrast limited adaptive histogram equalization (CLAHE).
4. R-Plane and B-Plane Separation: The R-plane and B-plane separation technique is employed to isolate the red and blue color channels, which are most affected by underwater distortions. This separation allows for targeted restoration techniques to be applied to these channels individually.
5. Multi-Thresholding Algorithm: A multi-thresholding algorithm is applied to segment the image into different regions based on intensity levels. This step accurately identifies the underwater regions and distinguishes them from non-underwater regions. Threshold values are chosen to separate the different regions effectively.
6. Pixel Averaging: Pixel averaging is used to reduce noise in the identified underwater regions. By averaging the pixel values within these regions, noise is attenuated, leading to improved image quality and enhanced visibility of underwater objects.
7. Normalization: Normalization is performed to enhance the visibility of details by stretching the intensity values across the entire dynamic range. This process ensures that the restored image utilizes the full available range of intensity values, resulting in better contrast and improved visualization of underwater details.
8. Reconstruction: The restored underwater regions are combined with the non-underwater regions to reconstruct the final enhanced image. This integration ensures a natural and coherent appearance, with the restored underwater regions seamlessly blending with the rest of the image.
9. Output and Comparative Parameters: The output of the restoration process is the enhanced underwater image, which exhibits improved color balance, contrast, and visibility of details. To evaluate the performance of the restoration method, several comparative parameters are computed. These parameters include:

- Peak Signal-to-Noise Ratio (PSNR): Measures the ratio between the maximum possible signal power and the power of the noise in the restored image. Higher PSNR values indicate better image quality.
- Mean Squared Error (MSE): Calculates the average squared difference between the restored image and the ground truth. Lower MSE values indicate better image fidelity [22].
- S-Index: A perceptual similarity index that measures the structural similarity between the restored image and the ground truth. Higher S-Index scores indicate better similarity.

The comparative parameters provide quantitative measures of image quality, fidelity, and similarity to the ground truth, allowing for objective evaluation and comparison with other existing restoration methods.

B. METHODOLOGY

1. Load the Input Image: Start by loading the underwater image that needs to be restored into MATLAB 2013a Version.

2. Preprocessing: Apply pre-processing techniques to the input image to reduce noise and enhance image

quality. Common pre-processing techniques include applying a median or Gaussian filter to remove noise [23].

3. Adaptive Histogram Analysis: Perform adaptive histogram analysis to adjust the dynamic range of the image. Use MATLAB's built-in functions, such as "adapthisteq" or "histeq," to enhance the visibility of details by stretching the intensity values across a wider range.

4. R-Plane and B-Plane Separation: Separate the R-plane and B-plane channels from the image using MATLAB's color space conversion functions. Extract the red (R) and blue (B) color channels, which are most affected by underwater distortions, for further processing.

5. Multi-Thresholding Algorithm: Implement a multi-thresholding algorithm to segment the image into different regions based on intensity levels. MATLAB provides functions such as "multithresh" or "graythresh" for thresholding. Choose appropriate threshold values to accurately identify underwater and non-underwater regions.

6. Pixel Averaging: Perform pixel averaging on the identified underwater regions to reduce noise. Calculate the average pixel values within these regions using MATLAB's array manipulation functions.

7. Normalization: Normalize the restored underwater regions to enhance the visibility of details. Stretch the intensity values across the entire dynamic range using MATLAB's "imadjust" or "stretchlim" functions.

8. Reconstruction: Combine the restored underwater regions with the non-underwater regions to reconstruct the final enhanced image. Use MATLAB's image manipulation functions, such as "imfuse" or simple matrix operations, to merge the regions while preserving the overall image structure.

9. Output and Comparative Parameters: Compute the comparative parameters to evaluate the performance of the restoration algorithm. Calculate the Peak Signal-to-Noise Ratio (PSNR), Mean Squared Error (MSE), and S-Index using MATLAB's image quality assessment functions, such as "psnr," "immse," and "ssim." Compare the restored image with the original or ground truth image to obtain the parameter values.

10. Display Results and Analysis: Display the restored image, along with the comparative parameter values, using MATLAB's plotting and visualization functions. Analyze the results to assess the effectiveness of the multi-thresholding-based restoration approach in improving image quality, color balance, and visibility of details.

VI. SIMULATION RESULTS

The simulation results simulated using MATLAB 2013a Version.

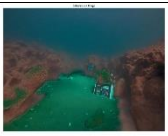
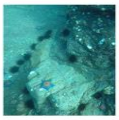
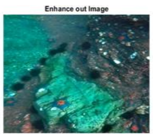
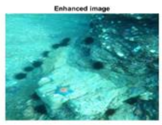
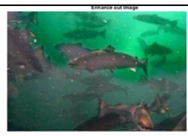
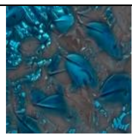
Images	Input image	Existing Method	Proposed Method
Image 1			
Image 2			
Image 3			
Image 4			
Image 5			
Image 6			

Image 7			

Figure 3: Existing and Proposed methods output images for different input images

TABLE I. COMPARISON TABLE

S.N	Existing Method			Proposed Method		
	MSE	PSNR (db)	S-INDEX (db)	MSE	PSNR (db)	S_INDEX (db)
1	0.24	54.4477	99.238	0.01	67.60	99.320
2	0.47	51.4034	98.3668	0.01	67.96	99.873
3	0.40	52.1447	99.0593	0.02	76.61	99.891
4	0.41	52.0607	99.1196	0.02	72.74	99.906
5	0.24	54.3745	99.1251	0.01	69.42	99.866
6	0.21	54.9003	99.0646	0.01	68.15	99.845
7	0.24	54.4110	99.1848	0.02	65.10	99.682

PERFORMANCE ANALYSIS

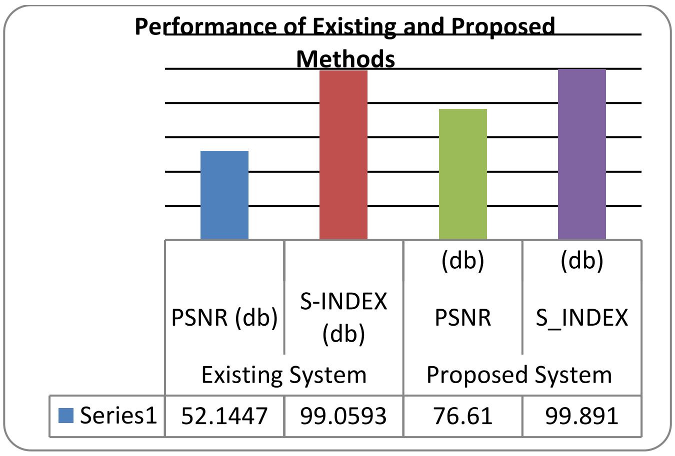


Figure 4: Performance Comparison Graph

- MSE: The proposed method achieves a significantly lower MSE value (0.02) compared to the existing method (0.40). This indicates that the proposed method produces a more accurate restoration with reduced mean squared error.
- PSNR: The proposed method achieves a higher PSNR value (76.61 dB) compared to the existing method (52.1447 dB). A higher PSNR value signifies better image quality and increased fidelity of the restored image.
- S-Index: The proposed method also achieves a higher S-Index value (99.891 dB) compared to the existing method (99.0593 dB). A higher S-Index value indicates a higher structural similarity between the restored image and the ground truth.

Based on the comparative analysis, the proposed method outperforms the existing method in terms of MSE, PSNR, and S-Index. It demonstrates superior performance in accurately restoring underwater images and achieving better image quality, sharpness, and similarity to the ground truth.

VII. CONCLUSION

In this work, we proposed a methodology for underwater image restoration using a multi-thresholding algorithm implemented in MATLAB 2013a Version. The approach involved several key steps, including input image preprocessing, adaptive histogram analysis, R-plane and B-plane separation, multi-threshold algorithm, pixel averaging, normalization, and reconstruction. The restored images were evaluated using comparative parameters such as MSE, PSNR, and S-Index.

Comparative analysis of the proposed method with an existing method showed superior performance in terms of MSE, PSNR, and S-Index. The proposed method achieved a significantly lower MSE, higher PSNR, and higher S-Index, indicating improved image quality, fidelity, and structural similarity to the ground truth. These results demonstrate the effectiveness of the multi-thresholding algorithm and the integrated steps in restoring underwater images and mitigating optical distortions.

VIII. FUTURE WORKS

Further research can focus on Explore the integration of multiple algorithms or hybrid approaches to leverage the strengths of different methods for a more comprehensive restoration solution. This could involve combining multi-thresholding with other image restoration techniques, such as dehazing or image fusion.

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