A novel underwater Image Enhancement technique

Alpana Sharma, Venkatadri Marriboyina,Kamlesh Gupta

Abstract **Image enhancement intensifies the information content of the image by accentuates the image edges and alters the visual impact of the observer. The contrast and sharpness of the images captured in underwater in general significantly deteriorates and diminish caused by the less perceptibility of the image due to the water medium's physical properties. In this work, we propose a novel underwater image enhancement technique by review the existing underwater enhancement methods. The proposed algorithm tested on standard underwater image enhancement methods with their standard parameters. The result shows the proposed method is better than standard algorithms and techniques.**

Index Terms*: *Underwater image, Fuzzy Intensification Operator, Discrete Cosine Transform.

I. INTRODUCTION

Image enhancement is to bring more visibility to the image and make it more appropriate to the required application. In today's scenario, the process of underwater image enhancement becomes an important area of study. Image enhancement intensifies the information content of the image by accentuates the image edges and alters the visual impact of the observer. The contrast and sharpness of the images captured in underwater suffers from poor colour contrast and poor visibility. Moreover, the quality of underwater images deteriorates due to the physical properties of the water medium, light scattering, reflection, and becomes more and more less visible as water depth increases. Hence this paper presents the literature review of the underwater image enhancement techniques, further a novel method devised for underwater image enhancement technique with comparative result analysis.

II. LITERATURE REVIEW

The recent advancement in computer vision technology, hardware, software and algebraic methods has led to improvements in several real time application areas includes underwater image enhancement. The primary objective of underwater image enhancement is to remove the scattered light effect and correct the colour cast in underwater [1]. Among various underwater image enhancement algorithms, Traditional Image Enhancement techniques, prior model image enhancement methods and the latest learning methods are most popular methods. The following table shows a review on present work and their advantages or limitations.

Table I : Literature Review

References	Methods / Techniques Applied	Advantages/ Limitations
[1]	Depth estimation method and adaptive attenuation curve for prior model-based methods	Sometimes these methods are invalid due to the complex environment and severe color cast.
[2],[9]	The morphological operator is used to detect background and contrast enhancement is carried out by using two operators based on weber's law	Obtains the background information to provide the clear scene in the images with poor light.
[3]	Recursive Mean Separate Histogram Equalization (RMSHE)	Selection of recursion level must be automated
[4]-[6]	Block based DCT coefficients for enhancing color images	The coarse quantization coefficients technique results visible artefacts
[7]	Histogram equalization Technique	The variations of gray distribution in the histogram causes side effects in this technique
[8]	Tuned tri-threshold fuzzy intensification operator	Applicable to the images in dusty weather only
[10]-[16]	Contrast enhancement technique using histogram equalization and fusion based methods	Computational complexity is more due to over exposed in images with noise in the input images along with the image features.
[17]	Equal area dualistic sub-image histogram equalization (DSIHE) technique	Gray level distribution in the histogram techniques causes side effects

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[18]	Minimum mean brightness error bi-histogram equalization (MMBEBHE)	Side effects due to the gray level distribution problem in the histogram
[19]-[20]	Dehazing algorithm	Greenish cast In enhanced images
[21]	GW (Gray World) method	GW method only applies in RGB color space to remove the color cast may not produce a visually pleasing image
[22]-[24]	Contrast limited adaptive histogram equalization	These methods improve the image quality, but noise amplification causes color distortion
[25]	Deep learning Based Methods	Domain knowledge and learning strategy applied for haze removal.

From the above-mentioned table I, the histogram equalization methods suffer from the more exposed areas of the images dominates the lower parts of the images. The traditional model methods suffer from noise amplification and color distortion in images. To overcome the afore mentioned limitations, we propose a novel method, employs a partition operation over the input histogram to divide in to sub histograms. Each sub-histogram goes through Histogram Equalization and is allowed to occupy a specified gray level range in the enhanced output image. Thus, a better overall contrast enhancement is gained by our proposed Dynamic Histogram Enhancement technique (DHET). The proposed technique ensures the consistency in preserving image details and is free from any side effects. The overall work is summarized as follows, Section 2 gives the proposed methodology which is used in this work. Section 3 reviews the standard parameters. The experimental results show the accuracy of proposed algorithm in section 4 and finally section 5 gives conclusion of this work.

III. PROPOSED HYBRID ALGORITHM

The proposed hybrid algorithm works in three different phases.

A.Block phase:

The color image is converted into gray image, which is divided into n x n blocks

B.DCT phase:

The Discrete Cosine Transform (DCT) method is used for enhancing local background illuminations of underwater image blocks that are created in first phase and then combined all the blocks to make a single image.

C.Tuned tri-threshold intensification operator phase:

Tuned tri-threshold intensification operator technique is used to improve the intensity of color image. This technique starts with the first tuning parameter, i.e. zeta, which is used to control the processed image color fidelity. After that the processed image is disintegrated into R, G and B channels. Now to calculate the value of intensification operator, two factors, named as the value of Γ and membership function, are required. Γ is basically represents the threshold value of the operator and the member function is used to set the pixel's values of a given channel between the range of 0 to 1.

The proposed algorithms steps are as follows:

Step 1: Input RGB color image.

Step 2: Convert RGB image into YCbCr image for better processing.

Step 3: Define block size [Here block size=8 are taken].

Step 4: Convert whole image into number of blocks.

Step 5: Adjust local background illumination using DCT.

Step 6: Merge all blocks of an image.

Step 7: Now convert YCbCr image into RGB color image.

Step 8: Set the value of zeta =0.5

Step 9: Convert the RGB image into its RGB layers

Step 10: Set the value of Γ_R, Γ_G and Γ_B into 0.5, 0.4 and 0.6 respectively.

Step 11: Compute the value of membership functions for each channel, following formulas are used-

$$f_{red} = \frac{[r - \min(r)]}{[\max(r) - \min(r)]} \quad (3)$$

$$f_{grn} = \frac{[g - \min(g)]}{[\max(g) - \min(g)]} \quad (4)$$

$$f_{blu} = \frac{[b - \min(b)]}{[\max(b) - \min(b)]} \quad (5)$$

Here $f_{red}, f_{grn}, f_{blu}$ represents the membership function's output for red, green and blue channels and {max, min} represent the maximum and minimum pixel values of input channels.

Step 12: Applied intensification operator by using following formulas-

$$K_{red} = 2 * \left(f_{red}(x,y)\right)^2, if\ f_{red}(x,y) \le \tau_{red} \quad (6)$$
$$Otherwise\ 1 - 2 * (1 - f_{red}(x,y))^2$$

$$K_{grn} = 2 * \left(f_{grn}(x,y)\right)^2,\ if\ f_{grn}(x,y) \le \tau_{grn} \quad (7)$$
$$Otherwise\ 1 - 2 * (1 - f_{grn}(x,y))^2$$

$$K_{blu} = 2 * \left(f_{blu}(x,y)\right)^2,\ if\ f_{blu}(x,y) \le \tau_{blu} \quad (8)$$
$$Otherwise\ 1 - 2 * (1 - f_{blu}(x,y))^2$$

Here $K_{red}, K_{blu}, K_{grn}$ represents the processed channels by intensification operator.

Step 13: Concatenate all channels to make a single processed RGB image.

Step 14: Finally received enhanced output image

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IV. PERFORMANCE PARAMETER

A. Peak signal to noise ratio (PSNR) and MSE

The PSNR (peak signal to noise ration) and MSE (mean square error) can evaluate the effectiveness of processed image.

$$PSNR = 10\ log_{10} \frac{255^2}{MSE} \ldots \qquad (9)$$

Where

$$MSE = \frac{\sum_{i=1}^{W} \sum_{j=1}^{H} (X_{ij} - X_{\tilde{ij}})}{W \times H} \ldots \qquad (10)$$

Where X_{ij} represents the original pixel and $X_{\tilde{ij}}$ for the reconstructed pixel and the size of all images are W × H.

B. Entropy

The value of entropy is calculated by using following formula:

$$H(m) = \sum_{i=0}^{M-1} p(m_i)\log\frac{1}{p(m_i)} \ldots \qquad (11)$$

WhereM denotes the total number of symbols and $p(m_i)$ is for the probability of occurrence of symbol mi.

C. Horizontal and vertical correlation

To calculate the correlation among two different horizontally and vertically adjacent pixels in enhanced image and original image respectively, the following two formulas are used

$$Cov(x,y) = E\big(x - E(X)\big)\big(y - E(y)\big) \ldots \qquad (12)$$

$$r_{xy} = \frac{Cov(x,y)}{\sqrt{D(x)}\sqrt{D(y)}} \ldots \qquad (13)$$

For numerical computation, the following formulas are used.

$$E(x) = \frac{1}{N}\sum_{i=1}^{N} x_i \ldots\ldots\ldots.. \qquad (14)$$

$$D(x) = \frac{1}{N}\sum_{i=1}^{N}\big(x_i - E(x)\big)\big(y - E(y)\big) \ldots \qquad (15)$$

$$Cov(x,y) = \frac{1}{N}\sum_{i=1}^{N}\big(x_i - E(x)\big)\big(y_i - E(y)\big) \ldots..(16)$$

Here where x and y represent two adjacent pixel values of an image.

V. EXPERIMENTAL RESULTS

The proposed novel underwater image enhancement algorithm tested with standard parameters and standard existing algorithms.

The following tables present the comparative analysis performed to check the efficiency of proposed technique with existing standard methods and parameters.

Table II: Comparison between proposed Algorithm with existing standard Algorithms.

Input Image	Parameters	Block Based Scheme	Improved CLAHE scheme	Contrast Adjustment Scheme	Proposed Scheme
	PSNR	8.050	8.301	9.887	20.896
	MSE	0	0.83635	0.869091	0.6154
	Entropy	0.7966	0.44268	0.702905	0.0350
	Horizontal correlation value	0.9406	0.93603	0.929246	0.8680
	Vertical correlation value	0.9548	0.95167	0.941855	0.8592
	PSNR	8.022	8.376	9.568	21.078
	MSE	0	0.88357	0.963373	0.9117
	Entropy	0.9327	0.21154	0.876366	0.0308
	Horizontal correlation value	0.9254	0.92086	0.922474	0.8671
	Vertical correlation value	0.9476	0.94014	0.928704	0.8427
	PSNR	8.022	8.318	9.982	21.046
	MSE	0	0.85948	0.859831	0.7928
	Entropy	0.9151	0.10036	0.658423	0.0315
	Horizontal correlation value	0.9364	0.95205	0.91087	0.8273
	Vertical correlation value	0.9517	0.95550	0.94106	0.8598
	PSNR	8.034	8.502	9.327	20.857
	MSE	0	0.872592	0.987022	0.964816
	Entropy	0.998268	1	1	0.035985
	Horizontal correlation value	0.993334	0.98883	0.993278	0.990902
	Vertical correlation value	0.994442	0.989065	0.993258	0.990076
	PSNR	8.022	8.337	9.758	21.533
	MSE	0	0.913214	0.890602	0.805952
	Entropy	0.998472	0.132943	0.768785	0.0225487
	Horizontal correlation value	0.943216	0.934104	0.936978	0.860287
	Vertical correlation value	0.934251	0.93799	0.920057	0.838114

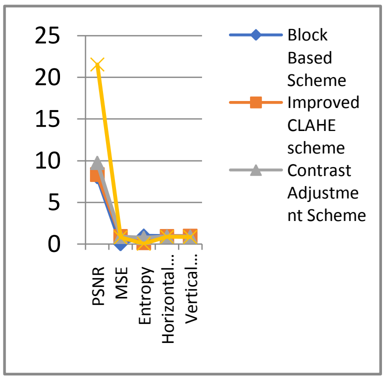
Input Image	**Comparative graph for the proposed and existing Methods**
	

Figure 1: Comparison of Proposed algorithm with Existing Methods Graph

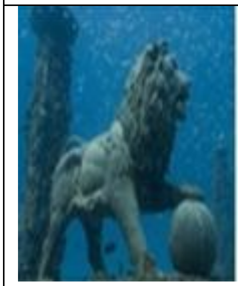
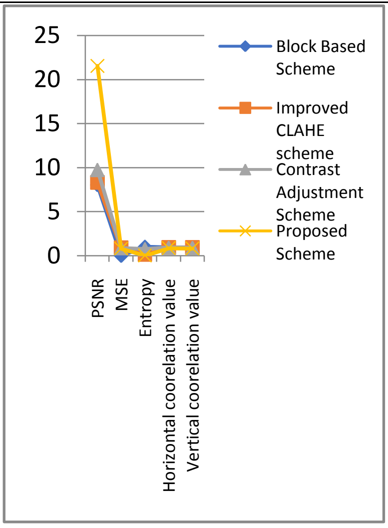
Input Image	Comparative graph for the proposed and existing Methods
	

Figure 2: Comparison of Proposed algorithm with Existing Methods

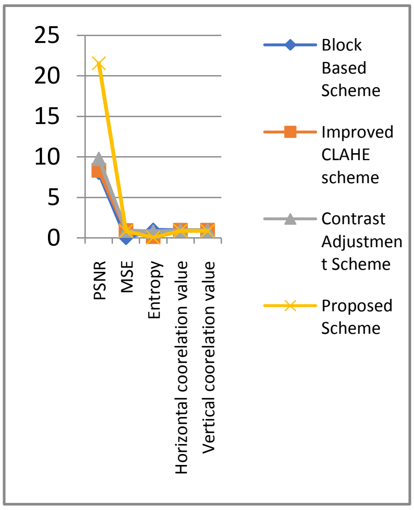
Input Image	Comparative graph for the proposed and existing Methods
	

Figure 3:Comparative Graph of Proposed and Existing Methods Graph.

Input Image	Comparative graph for the proposed and existing Methods

Figure 5:Comparative Graph of Proposed and Existing Methods Graph

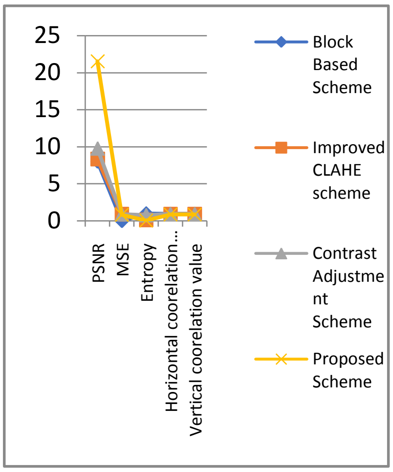
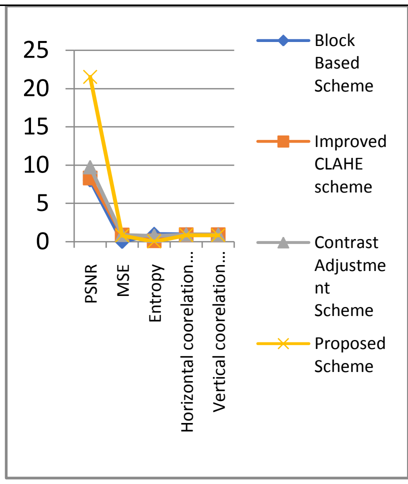
	

Figure 4:Comparative Graph of Proposed and Existing Methods Graph

Input Image	Comparative graph for the proposed and existing Methods
	

VI. Conclusion

In this paper, a novel underwater image enhancement technique DCT schemebased on tuned tri-threshold fuzzy intensification operator has been proposed. The DCT scheme is used for background detection of underwater images and there after image enhancement is done by using tuned tri-threshold based fuzzy intensification operator. Proposed scheme is compared with three existing schemes to check the efficiency of proposed scheme based on five parameters. All the experiments are performed on five different underwater images.

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Input Image	Block Based Scheme	Improved CLAHE scheme	Contrast Adjustment Scheme	Proposed Scheme

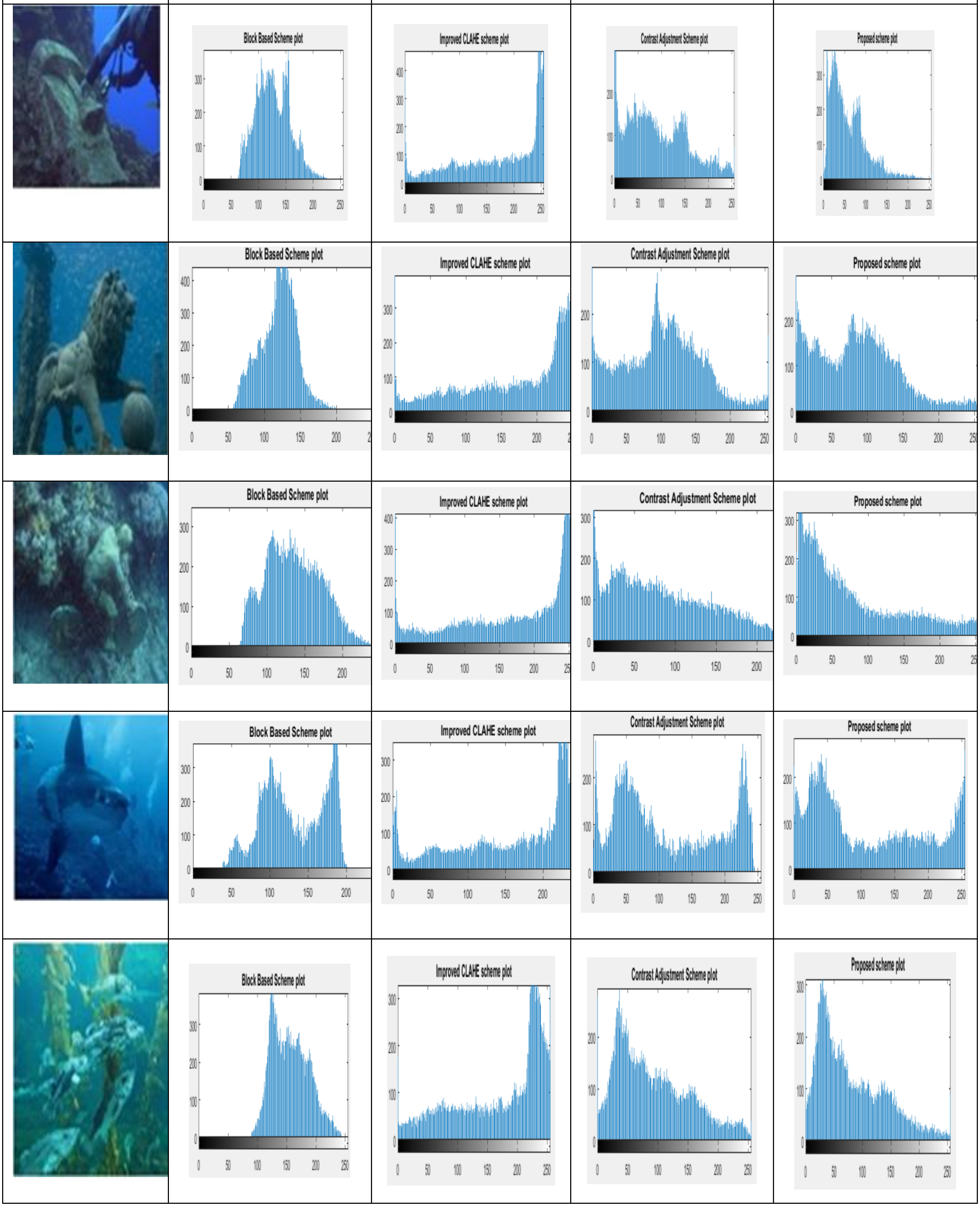

Figure 6:Histograms of image for existing and proposed Method

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