Adaptive Image Enhancement For Underwater Images Using Improved Gray World And Differential Gray-Levels Histogram Equalization

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Abstract- *Underwater images are poor in contrast, blurred and often contain color cast due to the scattering, light attenuation in water medium. This in turn makes captured images in low contrast and object recognition a difficult task. In some cases, underwater images are captured in very low illumination such object detection itself becomes a challenging task. Even though artificial light is attached with the underwater vehicles, the movement of vehicles also causes some turbidity in the water, resulting in limited visibility. Hence, for clear view, underwater images must undergo processing. This processing includes image enhancement and color cast reduction as the image suffers from poor contrast, non-uniform lighting, blurring etc. Even though, there are conventional methods available for enhancement like classical histogram equalization, contrast stretching, white balancing etc., they fail due to the unevenness in the illumination, non-uniform contrast and also fails to condense color cast. Hence conventional approach cannot be an ultimate approach for underwater images. Therefore, an adaptive algorithm which can effectively work for any kind of contrast and illumination is needed. Adaptive Gray World (AGW) and Differential Gray level Histogram Equalization (DHE) are proposed that are worked in parallel. AGW mainly concentrate on color cast present in image while DHE progresses the image contrast. The proposed method finally obtains chromaticity component from AGW and intensity component from DHE. Both of these components are combined to form the enhanced images. The outputs are increased in visibility, reduced in color cast and in most cases yield better quantitative scores.*

Keywords- image processing, image enhancement, underwater images, contrast correction, color cast reduction.

I. INTRODUCTION

Underwater imaging is one of the emerging fields in research area. Researchers are having high attention towards marine archeology.Underwater photography is usually done by scuba diving but the problem is images are not visually pleasing and did not contain much information. Capture high quality images in water medium always a difficult task. Light travels only up to a maximum of 100 meters in clear water, and less than a few meters in coastal and turbid water. The visibility is limited due to the fact that when light enters the water it is exponentially attenuated. Automatic Underwater Vehicle (AUV) is then introduced to capture images without manual interruption. Here also images are not clear because of physical property of the water. Image enhancement is mandatory for underwater images, when specialized hardware system such as, high performance camera compact or DSLR camera type are not available then Light scattering and light attenuation is biggest problem during photography. These effects results in low contrast and color cast. All in turn causes the underwater images low in contrast and hazy. Haze effect occurs due to unwanted particles such as sand, minerals and plankton exists in water [1] also underwater images suffer from degradation because of poor visibility conditions and effects such as light absorption, light reflection, bending of light and scattering of light [2]. Object recognition is difficult in underwater images due to blurred subjects and lowered contrast. In figure 1, there are only two fishes are identified; fishes present in upper-right corner are not visible clearly.

In this paper, we propose combined structure to remove color cast and improve the contrast of underwater image using Adaptive Gray World (AGW) and Differential Gray Level Histogram Equalization (DHE) respectively. Chromaticity component obtained from AGW and intensity component obtained from DHE are scaled to enhance underwater image.

II. LITERATURE SURVEY

Underwater imaging grabbed attention over the past several years as many algorithms have been established to enhance and restore the image characteristics after processing [3]. In the case of image enhancement M S Hitam et al. [3] presented an approach based on histogram equalization for contrast enhancement. Author introduced a new approach called mixture Contrast Limited Adaptive Histogram Equalization (CLAHE). This method enhances all type of images and operates on RGB and HSV color model

Green channel is commonly chosen reference color space and make it constant for calculate correction ratio. Global mean of each channel is represented as below,

$\bar{R} = \frac{1}{MN} \sum_{i \in M} \sum_{j \in N} R(i, j)$
based on Euclidian norm. Euclidean norm are used
for combine the results of both CLAHE on RGB
$\bar{G} = \frac{1}{MN} \sum_{i \in M} \sum_{j \in N} G(i, j)$ (1)
color model and CLAHE on HSV color model.
K Iqbal et al. [4] proposed a slide
$\bar{B} = \frac{1}{MN} \sum_{i \in M} \sum_{j \in N} B(i, j)$

stretching method that combines contrast stretching, saturation stretching and intensity stretching. Here the color contrast is equalized by contrast stretching of RGB algorithm and recover true color using saturation and intensity stretching of HIS algorithm. Further, K Iqbal et al. [5] proposed another underwater image enhancement method (UCM) which includes unsupervised color correction method for low quality underwater

Gray world method produces images with minimum color cast effect and make it little bit clear. Where $\bar{R}, \bar{G}, \bar{B}$ are global mean for each color channel of the input image of size $M \times N$. Gray world needs correction ratio for averaging color channel. Here, assumption is green channel is unchanged. Correction ratio for RGB channel is defined as
images, based on RGB and HSI color model. UCM is constructed by color balancing and contrast correction of RGB and HSI color space. Color cast problem is condensed by equalizing the color values and then stretching is used.
In the field of color cast removal numerous methods are developed to remove it. Fusion principle is one of the most well-known algorithms established by Ancuti et al. [6] for single underwater image. Here, white balance algorithm is implemented to expose dark regions. Fusion principle mainly focused on global contrast and edge sharpness.

Global mean method such as white balance algorithm is based on Gray world approach proposed by Buchsbaum et al. [7]. The assumption is average value of each RGB channel is averaged out to achromatic component. GW method mainly recommended for color cast removal of outdoor images [8]-[10]. Underwater color correction method is proposed by Bianco et al. [12] in $l\alpha\beta$ color space based on GW assumption. Gray World technique yields better results if an image is equally balanced otherwise it produces color distortion. Moreover the GW method produces the good results in low color cast situation. Secondly, this technique does not have any impact on illuminance of an image.

III. BACKGROUND STUDY

A. Gray World Algorithm

Gary world method is white balance approach that assumes the average out of each color channel is neutral gray. It is a traditional technique to reduce color cast of an image. Estimate colors cast illumination by computing the average color and compare it with gray value. Illusion is estimated by compute mean of each channel. Scaling factor is obtained by reference to one of three color channel in RGB color space [13].

$\beta b = \bar{B}$ (2)
$\beta g = \bar{G}$

Where βr, βb, βg correction ratio values and each channel are are adjusted by,

$R'(i, j) = \beta r \cdot R(i, j)$
$G'(i, j) = \beta g \cdot G(i, j)$ (3)
$B'(i, j) = \beta b \cdot B(i, j)$

Figure 1 shows the raw underwater images and enhanced image using GW method. GW method mainly concentrates on color cast removal but remains some greenish tint. We introduce an improved GW with DHE to remove color cast as well as increase contrast.

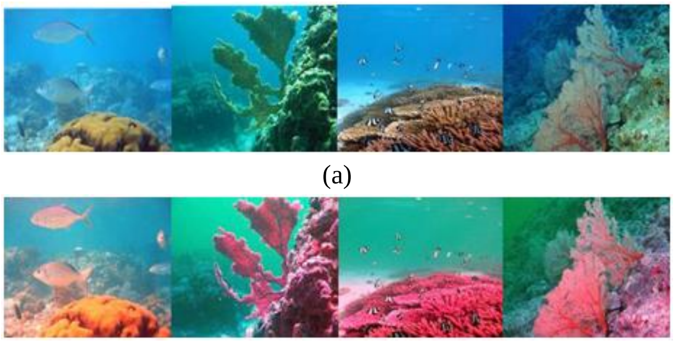
B. Histogram Equalization

Common technique for contrast improvement is histogram equalization. It is a simple spatial domain technique operates with intensity of an image. This technique compresses the low intensity pixels and expanses the high intensity pixels leading to dynamic range of image's histogram, results in overall contrast improvement of an image. Consider a digital image, which has the entire number of N pixels with gray-levels within the range [0, L-l]. The gray-level image histogram is a discrete function that is denoted as,

$$h(r_k) = n(k), \quad (4)$$

Where r_k the k-th gray level and n (k) is the number of pixels in the whole image with gray level r_k . The main hurdle with HE is the variations of gray distribution in the histogram causes side effects in this technique.

Image 1 Image 2 Image 3 Image 4



(a)

(b)

Figure 1. Visual comparrision of underwater images. (a) raw image (b) enhanced image by GW method

IV. PROPOSED WORK

A. Adaptive Gray World

AGW is an improved version of Gray World algorithm.GW method is not suits well for underwater images. It leaves some bluish or greenish tint to further analysis. AGW method introduces local mean of each channel. Gray World only focus on average (global mean) of each RGB channel but the problem is it did not work well for underwater images due to light attenuation and scattering in water medium. In proposed work,

Local mean is combined with global mean to further enhance the image. Local mean of each channel is computed using

$$R = \frac{1}{\quad} \sum \quad R(i, j)$$

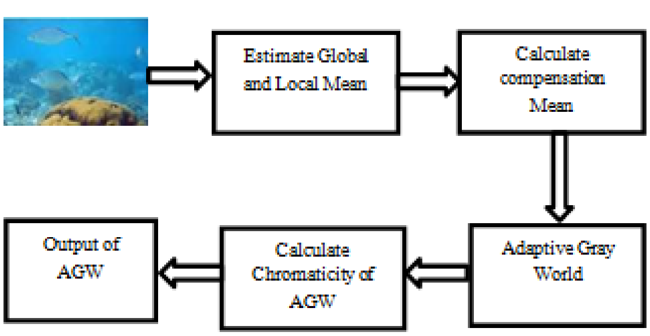


Figure 2 Flow Diagram of AGW

Finally AGW images are obtained by averaging out raw underwater image with respected

(2L+1)2

G = 1 (2L+1)2

L 1

(i,j)∈WL

∑(i,j)∈WL G(i, j)

(5)

compensation mean value which can defined as,

R′ = R(i,j)

R̄θ(i,j)

G′ = G(i,j)

(7)

B = (2L+1)2 ∑(i,j)∈WL B(i, j)

Ḡθ(i,j)

Where R, G, B are local mean and WL is moving

B′ = B(i,j)

B̄θ(i,j)

average window size for region with L is set to 10.This process is also known as local averaging operation; each pixel is replaced by average of all the values in local neighborhood. Compensation mean value for each channel is computed by using local and global mean values. It is combined and scaled as follow:

$$R(i, j) = \alpha. \bar{R} + (1 - \alpha). R(i, j)$$
$$G^{\theta}(i, j) = \alpha. \bar{G} + (1 - \alpha). G(i, j) \quad (6)$$
$$\bar{B}\theta(i, j) = \alpha. \bar{B} + (1 - \alpha). B(i, j)$$

Where R', G' and B' represent RGB channel of proposed Adaptive Gray World method. Figure 2 shows flow diagram of AGW method. Raw underwater image is given as input and then calculates Global and Local mean from that image and estimate compensation mean from Global and local mean of the image.

In figure 3 the visual comparison of underwater images by Gray World and Adaptive Gray World are presented. However GW yields slightly better images compared with AGW. The

Where R
, G
, B
represent compensation mean
Adaptive Gray World images are in high contrast
value for red, green and blue channel respectively and α scaling factor is limits from 0 to 1.
value but difficult is results are not visually pleasing images.

Image 1 Image 2 Image 3 Image 4

(a)

(b)

Figure 3 Visual comparisons of underwater images (a) enhanced images by GW (b) enhanced images by AGW

The chromaticity of AGW is obtained from results of AGW,
r $(i, j) =$ $R'(i,j)$
$(R\ (i,j)+G\ (i,j)+B\ (i,j))$

from 0 to $round(2\sqrt{5}.\ (L-1))$ where L=256. DHE maps input gray level m into output gray level n using Transformation function $TDHE\ (m)$.
m
$n = T$ $(m) = (L-1).\ (\sum x=0\ hd(x)$ (11)
DHE
$\sum L-1$)
g $(i, j) =$ $G'(i,j)$ (8)
$(R\ (i,j)+G\ (i,j)+B\ (i,j))$

b $(i, j) =$ $B'(i,j)$
$(R\ (i,j)+G\ (i,j)+B\ (i,j))$

Where $R'(i,\ j)$, $G'(i,\ j)$, $B'(i,\ j)$ represents red, green and blue channel of Adaptive Gray World are images and $rchr\ (i,\ j)$, $gchr(i,\ j)$, $bchr(i,\ j)$ represents the proportion of AGW chromaticity component.

B. Differential Gray-level Histogram Equalization Histogram equalization does not producebetter results because HE highly relies on distribution of gray levels of input image [18]. DHE uses the edge based information that is an important feature. In [19] DHE is established for contrast enhancement similarly DHE is adopted here for improve contrast based on intensity component. Differential gray-level histogram equalization is expressed by,
$x=0\ hd(x)$

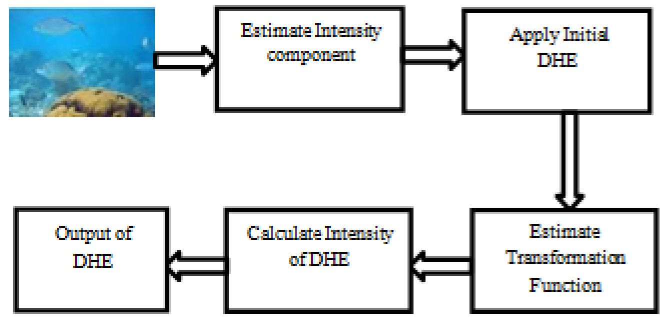


Figure 4 Flow diagram of DHE

Block diagram of Differential Gray Level Histogram are shown in above diagram. Intensity component $Iout\ (i,\ j)$of DHE can be obtained using

$Iout\ (i,\ j) = TDHE\ (I(i,\ j))$ (12)

At last, Chromaticity component of AGW and Intensity component of is scaled to attain the
$hd(m) = \sum(i,j)\in Dm$
$a(i,\ j)$
(9)
enhanced image using
$Rout(i,\ j) = 3.\ rchr\ (i,\ j).\ Iout\ (i,\ j)$
Where $a(i,\ j) = round\ (\sqrt{a(i,j)2\ + a(i,j)2}\ )$ (10)
Hor
Ver

$Gout(i,\ j) = 3.\ gchr(i,\ j).\ Iout\ (i,\ j)$(13)
$a(i,j) = [I(i+1, j+1) + 2.\ I(i+1, j) + I(i+1, j-1)] -$
$Bout\ (i,\ j) = 3.\ bchr\ (i,\ j).\ Iout\ (i,\ j)$
$[I(i-1, j+1) + 2.\ I(i-1, j) + I(i-1, j-1)]$

$a^{(i,j)} = [I(i+1, j+1) + 2.\ I(i, j+1) + I(i-1, j+1)] - [I(i+1, j-1) + 2.\ I(i, j-1) + I(i-1, j-1)]$
Here Dm is a area composed of pixels and m takes the values between 0 and 255. Range of a(i,j) is

The results are obtained by combine both Gray World and Adaptive Gray World results. Figure 5 shows the work flow of proposed method that is combined parallel structure of GW and AGW methods using scaling factor 3.

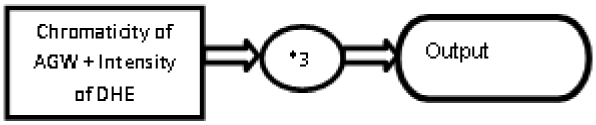


Figure 5 Flow diagram of proposed work

V. EXPERIMENTAL RESULTS

The experimental results of GW with DHE and AGW with DHE are presented in this section and quantitative, qualitative evaluations of

A. Quantitative Analysis

Quantitative evaluation used to verify the performance of proposed methods. The factors included are ENTROPY, PCQI, UCIQE, MAE and PSNR metrics. Entropy is used to validate the information content. Higher entropy value indicates the image contains more information compared to other images. It is calculated usingproposed and existing method also carried out using following metrics: Entropy, Underwater

$Entropy = -\sum^{n}$
$pi\ (log2pi\ )$
(14)

Color Image Quality Evaluation (UCIQE) [20], Patch-based Contrast Quality Index (PCQI) [21], Mean Absolute Error (MAE) and Peak Signal to Noise Ratio (PSNR).

B. Qualitative Analysis

In Underwater image processing there is no ground truth images available for compare and evaluate the enhanced images. Qualitative Analysis is done by examine all proposed images and validate if the image expose dark regions better. Input images [6], [14] are captured in different locations with different objects are chosen for experimental analysis Using visual comparison as shown in Figure 6 we have compared proposed work with other techniques as mentioned above. Many platforms are available for comparison and quantification of visual enhancement of underwater images, which have helped comparing proposed work with contemporary techniques.

Gray World technique is a traditional approach of color constancy, which is based on the assumption that the average reflectance of surfaces in the world is achromatic. This method slightly increase visual effect but fails to recover the real scene when the image has massive color dominant and also remains some greenish tint. Gray world

Where pi is probability distributed function of gray level. Entropy is calculated as the summation of products of the probability of occurrence and inverse log of the probability of occurrence. Next metric is presented by M. Yang et al. [20]. Underwater image quality evaluation UCIQE is computed using

$UCIQE = c1 \times \sigma c + c2 \times con1 + c3 \times \mu s$ (15) where, σc is the standard deviation of chroma,

$con1$is the contrast of luminance and μs is the average of saturation, and $c1$, $c2$, $c2$are weighted coefficients. For underwater monitoring as

surveyed by the researchers the emblematic value of coefficients are $c1$ = 0.4680, $c2$= 0.2745, $c3$= 0.2576. Then Patch Contrast Quality Index is proposed by S Wang et al [21] is defined as

$PCQI(X, Y) = qi(x, y)qc(x, y)qs(x, y)$ (16)

where $qi\ (x,\ y)$ is the mean intensity, $qc(x,\ y)$is the signal strength and $qs(x,\ y)$is the structural information. If the Image have higher PCQI value it indicates image has better contrast. Mean Absolute Error (MAE) is a qualitative measure of two variables or images. Let X and Y be two variables of paired observations that express the same incident.

technique operates on globally which gives the

$MAE = 1 \sum^{n}$

$=1$

$|X - Y\ |$

(17)

global enhancement of image.

Adaptive Gray World enhances image both globally and locally also it works with each channel. Here, the assumption is make green channel constant. Underwater images are highly affected by green color tint. This algorithm works well when green channel is unchanged. Calculate increasing factor value using green channel. However, the result is not visually pleasing and object recognition becomes more difficult.

Compared to existing methods as mentioned above, we are able to expose the shadowy regions much effectively. As shown in figure 6, the images obtained by applying our algorithm is characterized by enhanced contrast, optimized visibility and retaining a natural appearance.

$n \quad i=1 \quad i \qquad i$

Where Xi is original and Yi is predicted value. MAE value is the average absolute differences between prediction and actual observation over the test samples where all individual differences have equal weight. The smaller MAE values indicates the image has lower error rate.

Peak Signal to Noise Ratio is operated with signal and power. It is defined as the ratio of maximum possible value of a signal and the power of distorting noise that affects the quality of its representation. The dimensions of the two images must be the same. Mathematical representation of the PSNR is as follows

$$PSNR = 20log\left(\frac{256}{\sqrt{MSE}}\right) \quad (18)$$

The proposed method has better quantitative scores compared to GW with DHE method.

TABLE I QUANTITATIVE EVALUATIONS OF ENTROPY FOR FIGURE 6

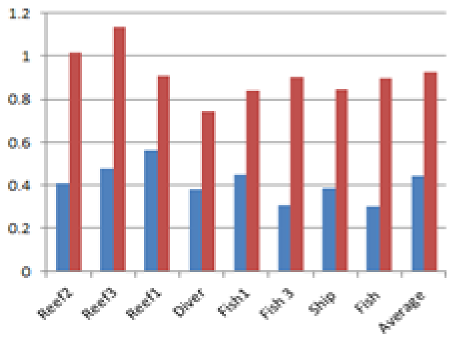
Image	GW+DHE	Proposed Method
Reef2	6.5017	7.7873
Reef3	6.6893	7.8792
Reef1	6.2356	7.2312
Diver	6.3860	7.3344
Fish1	6.0030	7.2214
Fish 3	6.1589	7.6510
Ship	6.6548	7.1107
Fish	6.7463	7.3721
Average	**6.3817**	**7.4109**

TABLE II QUANTITATIVE EVALUATIONS OF PCQI FOR FIGURE 6

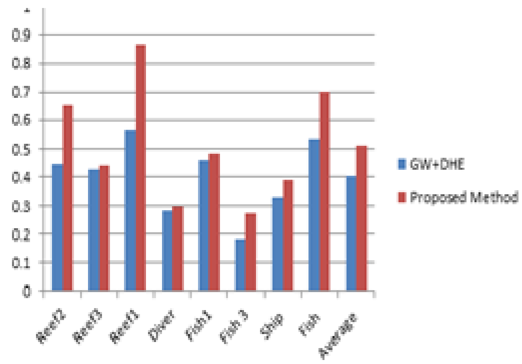
Image	GW+DHE	Proposed Method
Reef2	0.41071	1.01640
Reef3	0.47707	1.13880
Reef1	0.56489	0.90772
Diver	0.37784	0.74339
Fish1	0.44964	0.83860
Fish 3	0.30770	0.90089
Ship	0.38834	0.84714
Fish	0.30273	0.89977
Average	**0.44098**	**0.92658**

TABLE III QUANTITATIVE EVALUATIONS OF UCIQE FO FIGURE 6

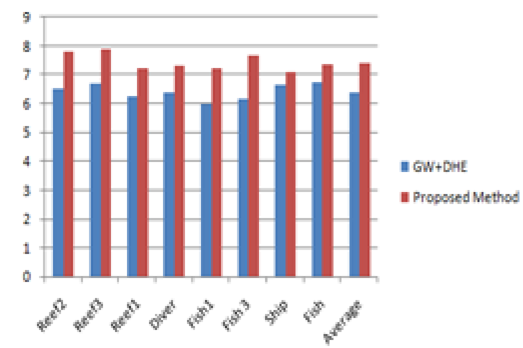
Image	GW+DHE	Proposed Method
Reef2	0.4442	0.6520
Reef3	0.4275	0.4379
Reef1	0.5614	0.8661
Diver	0.2859	0.3001
Fish1	0.4596	0.4820
Fish 3	0.1842	0.2735
Ship	0.3328	0.3874
Fish	0.5366	0.7025
Average	**0.4040**	**0.5126**



(a)



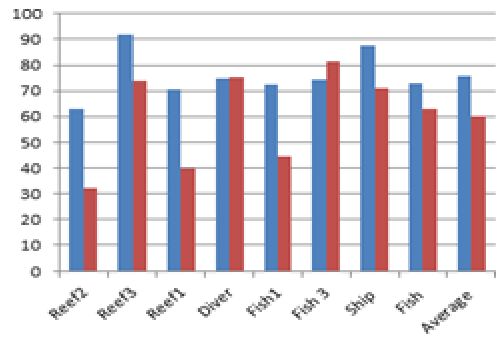
(b)



(c)

TABLE IV QUANTITATIVE EVALUATIONS OF MAE FOR FIGURE 6

Image	GW+DHE	Proposed Method
Reef2	63.0094	32.2844
Reef3	91.8032	73.8449
Reef1	70.6279	39.7132
Diver	74.7395	75.3472
Fish1	72.3623	44.3410
Fish 3	74.2980	81.3320
Ship	87.4582	70.7970
Fish	73.0878	62.9353
Average	**75.9232**	**60.0743**



(d)

Figure 5 Results of quantitative scores (a) Entropy (b) PCQI (c) UCIQE (d) MAE

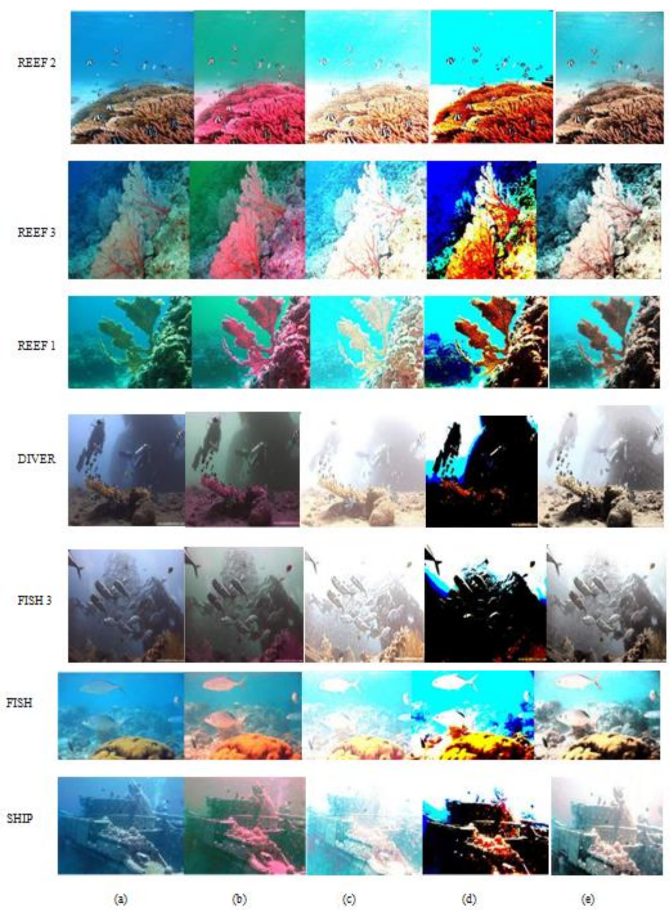


Figure 6 Visual Comparision Of Underwater Images (a) input images (b) enhanced images using gray world (c) enhanced images using adaptive gray world (d) enhanced images using GW+DHE (e) enhanced images using AGW+DHE

V. CONCLUSION

In this work, underwater image enhancement algorithms namely, Adaptive Gray World (AGW), Differential Histogram Equalization (DHE) are proposed. To qualitatively assess the visibility factor, each algorithm is applied to set of complex and challenging underwater images. The enhanced images are characterized by improved Entropy, Underwater Color Image Quality Evaluation (UCIQE), Patch Structure representation for Quality assessment of contrast changed Images (PCQI), and Mean Absolute Error (MAE), Peak Signal Noise Ratio (PSNR) factors respectively. The performance metrics used for evaluating each algorithm are presented and discussed at appropriate places in each chapter. The algorithms are compared with the traditional techniques and the results are presented both subjectively and objectively. The better exposure of dark regions and details are significantly enhanced in underwater images.

REFERENCES

[1] J Y Chiang and Ying-Ching Chen, “Underwater Image Enhancement by Wavelength Compensation and Dehazing,” IEEE Transactions on Image Processing, vol. Apr. 2012.

[2] T. C. Aysun and E. Sarp,Visual Enhancement of Underwater Images Using Empirical Mode Decomposition, Expert Systems with Applications.

[3] M S Hitam, W N Yussof, and W H, E A. Awalludin, "Mixture contrast limited adaptive histogram equalization for underwater image enhancement", IEEE International Conference on Computer Applications Technology, 2013.

[4] K Iqbal, Rsalina abdul Salam, Azam Osman, “Underwater Image Enhancement using an Integrated Color Model”, IAENG International Journal of Computer Science, 2009.

[5] K. Iqbal, M. Odetayo, and A. James, “Enhancing the low quality images using Unsupervised Colour Correction Method,” in 2010 IEEE International Conference on Systems, Man and Cybernetics, 2010.

[6] C. Ancuti, C. O. Ancuti, T. Haber, and P. Bekaert, “Enhancing underwater images and videos by fusion,” in 2012 IEEE Conference on Computer Vision and Pattern Recognition, 2012.

[7] G. Buchsbaum, “A spatial processor model for object colour perception,” Journal of the Franklin Institution, 1980.

[8] V. Chikane and C. S. Fuh, “Automatic white balance for digital still cameras,” Journal of Information Science and Engineering.

[9] W. J. Kyung, D. C. Kim, H. G. Ha, and Y. H. Ha, “Color enhancement for faded images based on multi-scale gray world algorithm,” in 2012 IEEE 16th International Symposium on Consumer Electronics.

[10] S.-C. Tai, T.-W. Liao, Y.-Y. Chang, and C.-P. Yeh, “Automatic White Balance Algorithm through the Average Equalization and Threshold,” in 8th International Conference on Information Science and Digital Content Technology (ICIDT), 2012.

C. Li, J. Guo, S. Chen, Y. Tang, Y. Pang, and J. …ang, "Underwater image restoration based on minimum information loss principle and optical properties of underwater imaging," in 2016.

[12] G. Bianco, M. Muzzupappa, F. Bruno, R. Garcia, and L. Neumann, "A new color correction method for underwater imaging," in ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2015.

[13] E. Y. Lam, "Combining gray world and retinex theory for automatic white balance in digital photography," in Proceedings of the Ninth International Symposium on Consumer Electronics, 2005.

[14] N. Carlevaris-Bianco, A. Mohan, and R. M. Eustice, "Initial results in underwater single image dehazing," in Oceans 2010 Mts/Ieee Seattle, 2010.

[15] R. Schettini and S. Corchs, "Underwater image processing: state of the art of restoration and image enhancement methods," EURASIP Journal on Advances in Signal Processing, vol. 2010.

[16] A. S. A. Ghani and N. A. M. Isa, "Underwater image quality enhancement through Rayleigh- stretching and averaging image planes," International Journal of Naval Architecture and Ocean Engineering, 2014.

[17] A. S. A. Ghani and N. A. M. Isa, "Underwater image quality enhancement through integrated color model with Rayleigh distribution," Applied Soft Computing, vol. 27,Feb. 2015.

[18] A. S. A. Ghani and N. A. M. Isa, "Enhancement of low quality underwater image through integrated global and local contrast correction," Applied Soft Computing, Dec. 2015.

[19] K. Murahira and A. Taguchi, "A novel contrast enhancement method using differential gray-levels histogram," in 2011 International Symposium on Intelligent Signal Processing and Communications Systems.

[20] S. Wang, K. Ma, H. Yeganeh, Z. Wang, and W. Lin, "A PatchStructure Representation Method for Quality Assessment of Contrast Changed Images," IEEE Signal Processing Letters, Dec. 2015.

[21] M. Yang and A. Sowmya, "An Underwater Color Image Quality Evaluation Metric," IEEE Transactions on Image Processing, , Dec. 2015.