Underwater Image Enhancement 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 that object detection itself becomes a challenging task. 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. 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 results.*

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. 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 high degradation because of poor environment conditions and effects such as light absorption, light reflection, and light scattering [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 based on Euclidian norm. Euclidean norm are used for combine the results of both CLAHE on RGB color model and CLAHE on HSV color model. K Iqbal et al. [4] proposed a slide 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.

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. RELATED WORK

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]. 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,

$$\bar{R} = \frac{1}{MN}\sum_{i\in M}\sum_{j\in N} R(i,j)$$
$$\bar{G} = \frac{1}{MN}\sum_{i\in M}\sum_{j\in N} G(i,j) \quad (1)$$
$$\bar{B} = \frac{1}{MN}\sum_{i\in M}\sum_{j\in N} B(i,j)$$

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

$$\beta_r = \frac{\bar{G}}{\bar{R}}$$
$$\beta_b = \frac{\bar{G}}{\bar{B}} \quad (2)$$
$$\beta_g = \bar{G}$$

Where $\beta_r, \beta_b, \beta_g$ correction ratio values and each channel are are adjusted by,

$$\hat{R}(i,j) = \beta_r . R(i,j)$$
$$\hat{G}(i,j) = \beta_g . G(i,j) \quad (3)$$
$$\hat{B}(i,j) = \beta_b . B(i,j)$$

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 total number of N pixels with gray-levels in 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.

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

$$R^L = \frac{1}{(2L+1)^2}\sum_{(i,j)\in W_L} R(i,j)$$
$$G^L = \frac{1}{(2L+1)^2}\sum_{(i,j)\in W_L} G(i,j) \quad (5)$$

$$\bar{B}^{L} = \frac{1}{(2L+1)^2}\sum_{(i,j)\in W_L} B(i,j)$$

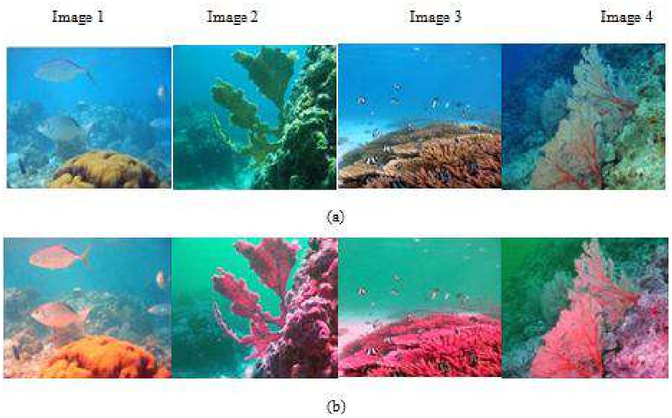

Figure 1. Visual comparrision of underwater images. (a) raw image (b) enhanced image by GW method

Where $\bar{R}^L, \bar{G}^L, \bar{B}^L$ are local mean and W_L is moving 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:

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

Where $\bar{R}^{\theta}, \bar{G}^{\theta}, \bar{B}^{\theta}$ represent compensation mean value for red, green and blue channel respectively and α scaling factor is limits from 0 to 1.

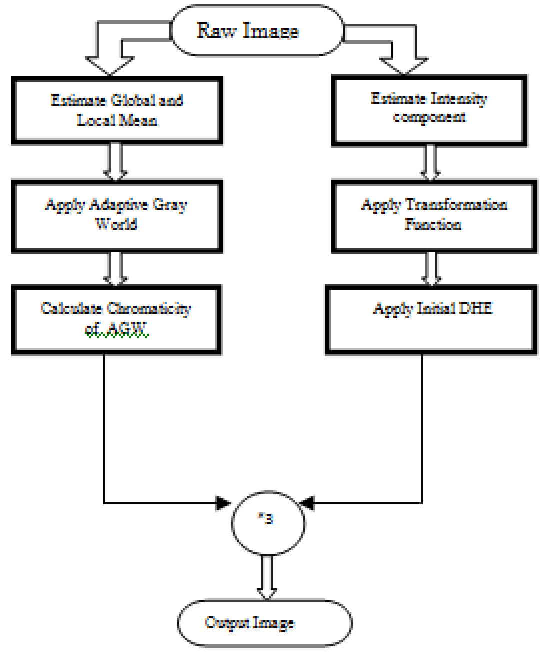

Figure 2 Flow Diagram of proposed work

Finally AGW images are obtained by averaging out raw underwater image with respected compensation mean value which can defined as,

$$\begin{aligned} R' &= \frac{R(i,j)}{\bar{R}^{\theta}(i,j)} \\ G' &= \frac{G(i,j)}{\bar{G}^{\theta}(i,j)} \quad (7) \\ B' &= \frac{B(i,j)}{\bar{B}^{\theta}(i,j)} \end{aligned}$$

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 Adaptive Gray World images are in high contrast value but difficult is results are not visually pleasing images.

The chromaticity of AGW is obtained from results of AGW,

$$r_{chr}(i,j) = \frac{R'(i,j)}{(R'(i,j) + G'(i,j) + B'(i,j))}$$

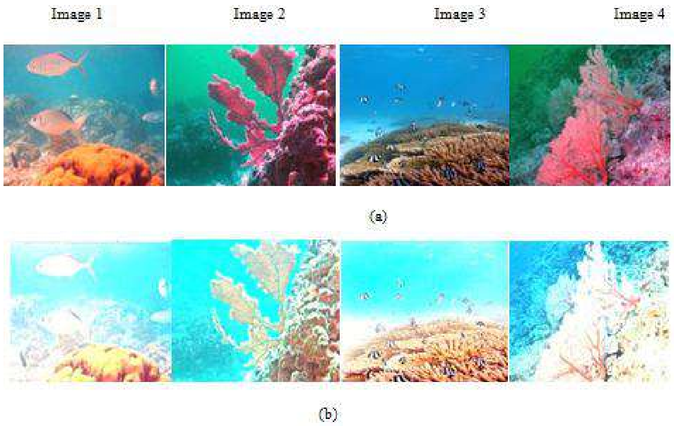

Figure 3 Visual comparisons of underwater images (a) enhanced images by GW (b) enhanced images by AGW

$$g_{chr}(i,j) = \frac{G'(i,j)}{(R'(i,j)+G'(i,j)+B'(i,j))} \qquad (8)$$
$$b_{chr}(i,j) = \frac{B'(i,j)}{(R'(i,j)+G'(i,j)+B'(i,j))}$$

Where $R'(i,j), G'(i,j), B'(i,j)$ represents red, green and blue channel of Adaptive Gray World are images and $r_{chr}(i,j), g_{chr}(i,j), b_{chr}(i,j)$ represents the proportion of AGW chromaticity component.

B. Differential Gray-level Histogram Equalization

Histogram equalization does not produce better 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,

$$h_d(m) = \sum_{(i,j)\in D_m} a(i,j) \qquad (9)$$

Where $a(i,j) = round\left(\sqrt{a_{Hor}^{(i,j)^2} + a_{Ver}^{(i,j)^2}}\right)$ (10)

$$a_{Hor}^{(i,j)} = [I(i+1,j+1) + 2.I(i+1,j) + I(i+1,j-1)] - [I(i-1,j+1) + 2.I(i-1,j) + I(i-1,j-1)]$$

$$a_{Ver}^{(i,j)} = [I(i+1,j+1) + 2.I(i,j+1) + I(i-1,j+1)] - [I(i+1,j-1) + 2.I(i,j-1) + I(i-1,j-1)]$$

Here D_m is a area composed of pixels and m takes the values between 0 and 255. Range of a(i,j) is 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 $T_{DHE}(m)$.

$$n = T_{DHE}(m) = (L-1).\left(\frac{\sum_{x=0}^{m} h_d(x)}{\sum_{x=0}^{L-1} h_d(x)}\right) \qquad (11)$$

Intensity component $I_{out}(i,j)$ of DHE can be obtained using

$$I_{out}(i,j) = T_{DHE}(I(i,j)) \qquad (12)$$

At last, Chromaticity component of AGW and Intensity component of is scaled to attain the enhanced image using

$$R_{out}(i,j) = 3.r_{chr}(i,j).I_{out}(i,j)$$
$$G_{out}(i,j) = 3.g_{chr}(i,j).I_{out}(i,j) \qquad (13)$$
$$B_{out}(i,j) = 3.b_{chr}(i,j).I_{out}(i,j)$$

The results are obtained by combine both Gray World and Adaptive Gray World results. Figure 4 shows the work flow of proposed method that is combined parallel structure of GW and AGW methods using scaling factor 3.

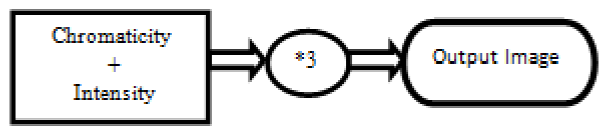

Figure 4 Combined Structure of proposed method

V. EXPERIMENTAL RESULTS

The experimental results of GW with DHE and AGW with DHE are presented in figure 5

Figure 5 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

Input images [6], [14] are captured in different locations with different objects are chosen for experimental analysis Using visual comparison as shown in Figure 5 we have compared proposed work with other techniques as mentioned above.

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 technique operates on globally which gives the 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 5, the images obtained by applying our algorithm is characterized by enhanced contrast, optimized visibility and retaining a natural appearance.

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 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.

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