Underwater Image Enhancement Using Fusion Strategy for Color Cast Removal and Contrast Enhancement

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***Abstract* - Underwater images usually lack contrast and suffer from color distortion due to light beam scattering and attenuation. Light scattering is due to the presence of suspended particles in water in form of both organic and inorganic material which reflects and deflects the light in an unpredictable manner before it reaches the sensor and results in an image which is low in contrast. Water as a medium readily absorbs light, and moreover different wavelengths of light as absorbs at different rates. Furthermore, the longer wavelength is absorbed first and it results in the underwater environment with a dominant green-bluish tone. Adaptive Gray World (AGW) and Differential Gray level Histogram Equalization (DHE) are implemented to reduce the color cast and improve the contrast of an image. Most of the underwater images are often suffered by haze effect. Haze is a degradation effect that affects the quality of an image and reduces scene visibility. Fusion method is proposed to remove haze from an underwater image. It includes blending of two images obtained from gamma correction and edge sharpening. Fusion carried out by calculating weight maps from gamma corrected image and edge sharpened image.**

***Index Terms* - Color cast removal, Contrast Enhancement, Fusion Principle Haze removal, Image Processing, Underwater Image Enhancement.**

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 this paper, Adaptive Gray World with Differential Gray Level Histogram Equalization for color cast removal a naive fusion for haze removal are proposed to enhance the scene visibility.

II. RELATED WORK

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. PROPOSED WORK

A. Adaptive Gray World

AGW is an improved version of Gray World algorithm.GW method is not suiting 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

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

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

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

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:

$$\bar{R}^{\theta}(i,j) = \alpha.\bar{R} + (1-\alpha).\bar{R}^{L}(i,j)$$

$$\bar{G}^{\theta}(i,j) = \alpha.\bar{G} + (1-\alpha).\bar{G}^{L}(i,j) \qquad (2)$$

$$\bar{B}^{\theta}(i,j) = \alpha.\bar{B} + (1-\alpha).\bar{B}^{L}(i,j)$$

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.

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

$$R' = \frac{R(i,j)}{\bar{R}^{\theta}(i,j)}$$

$$G' = \frac{G(i,j)}{\bar{G}^{\theta}(i,j)} \qquad (3)$$

$$B' = \frac{B(i,j)}{\bar{B}^{\theta}(i,j)}$$

Where R', G' and B' represent RGB channel of proposed Adaptive Gray World 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 2 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,

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

$$g_{chr}(i,j) = \frac{G'(i,j)}{(R'(i,j)+G'(i,j)+B'(i,j))} \quad (4)$$

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

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. DHE uses the edge-based information that is an important feature. In [13] 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,

$$h_d(m) = \sum_{(i,j)\in D_m} a(i,j) \quad (5)$$

Where $a(i,j) = round\left(\sqrt{a_{Hor}^{(i,j)^2} + a_{Ver}^{(i,j)^2}}\right)$ (6)

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

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

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 $T_{DHE}(m)$.

$$n = T_{DHE}(m) = (L-1).\left(\frac{\sum_{x=0}^{m} h_d(x)}{\sum_{x=0}^{L-1} h_d(x)}\right) \quad (7)$$

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

$$I_{out}(i,j) = T_{DHE}(I(i,j)) \quad (8)$$

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

$$R_{out}(i,j) = 3.r_{chr}(i,j).I_{out}(i,j)$$

$$G_{out}(i,j) = 3.g_{chr}(i,j).I_{out}(i,j) \quad (13)$$

$$B_{out}(i,j) = 3.b_{chr}(i,j).I_{out}(i,j)$$

The results are obtained by combine both Gray World and Adaptive Gray World results. Figure 1 shows the workflow of proposed method that is combined parallel structure of GW and AGW methods using scaling factor 3.

C. NAIVE FUSION

Input of fusion is comes from two modules gamma correction and edge sharpening. Gamma correction is applied to white balanced version of an image aims to correct the global contrast of too brighter area. Second input is sharpened version of white balanced image. Unsharp masking is used to sharp the image. Sharpened image is defined as,

$$S = \frac{I+N\{I-G*I\}}{2} \quad (9)$$

Where N{.} is linear normalization operator also refer as histogram stretching. This operator used to shift and scales all color pixel intensities of an image with a unique shifting and scaling factor.

Weights of Fusion process:

1. Laplacian Weight map (W_L): estimates global contrast by compute absolute value of a laplacian filter applied on luminance channel. This weight map is also known as luminance weight map of an image.
2. Saliency Weight map (W_S): aims to recover salient objects that lose their prominence in water medium. But the problem is this map favor only highlighted area with high luminance value.
3. Saturation Weight map (W_{Sat}): this emphasize with chromatic information of an image by take highly saturated regions.

$$W_{Sat} = \sqrt{1/3[(R_k - L_k)^2 + (G_k - L_k)^2 + (B_k - L_k)^2]} \quad (10)$$

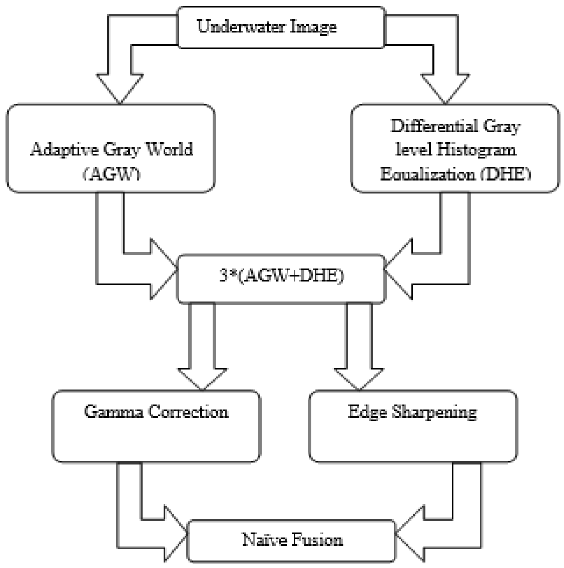

Figure 1 Block diagram of proposed naive fusion method

Normalized Weight Maps:

Aggregated weight map is obtained by summing up the three weight maps mentioned above. Aggregated maps are normalized by dividing each weight map by sum of all weight maps.

Finally, naive fusion is constructed by consider normalized weight maps and input of the fusion principle. Fusion is denoted as,

$\mathcal{R}(x) = \sum_{k=1}^{K} \bar{W}_k(x) I_k(x)$ (11)

Where I_k denotes input (K=2) that is weighted by normalized weight maps. R(x) is output image of naïve fusion.

Figure 1 shows workflow of naïve fusion in which white balanced version of an image is obtained by using Adaptive Gray World and Differential histogram equalization and then gamma correction unsharp masking is performed to give input of naïve fusion.

IV.RESULT ANALYSIS

The experimental results of AGE+DHE and naive fusion are presented in figure 2 Input images [6], [11] are captured in different locations with different objects are chosen for experimental analysis Using visual comparison as shown in Figure 2 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 increases 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.

AGW with DHE is also failed to exposure high region but naive fusion obtains with good and high scene visibility. Compared to existing methods as mentioned above, we are able to expose the shadowy regions much effectively. As shown in figure 2, 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), gamma correction, edge sharpening and Naive Fusion are proposed. To qualitatively assess the visibility factor, each algorithm is applied to set of complex and challenging underwater images. AGW with DHE images leave some space for further implementation. The images obtained from AGW with DHE was suffered from haze effect. Naive Fusion is implemented to remove the haze present in the image. 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.

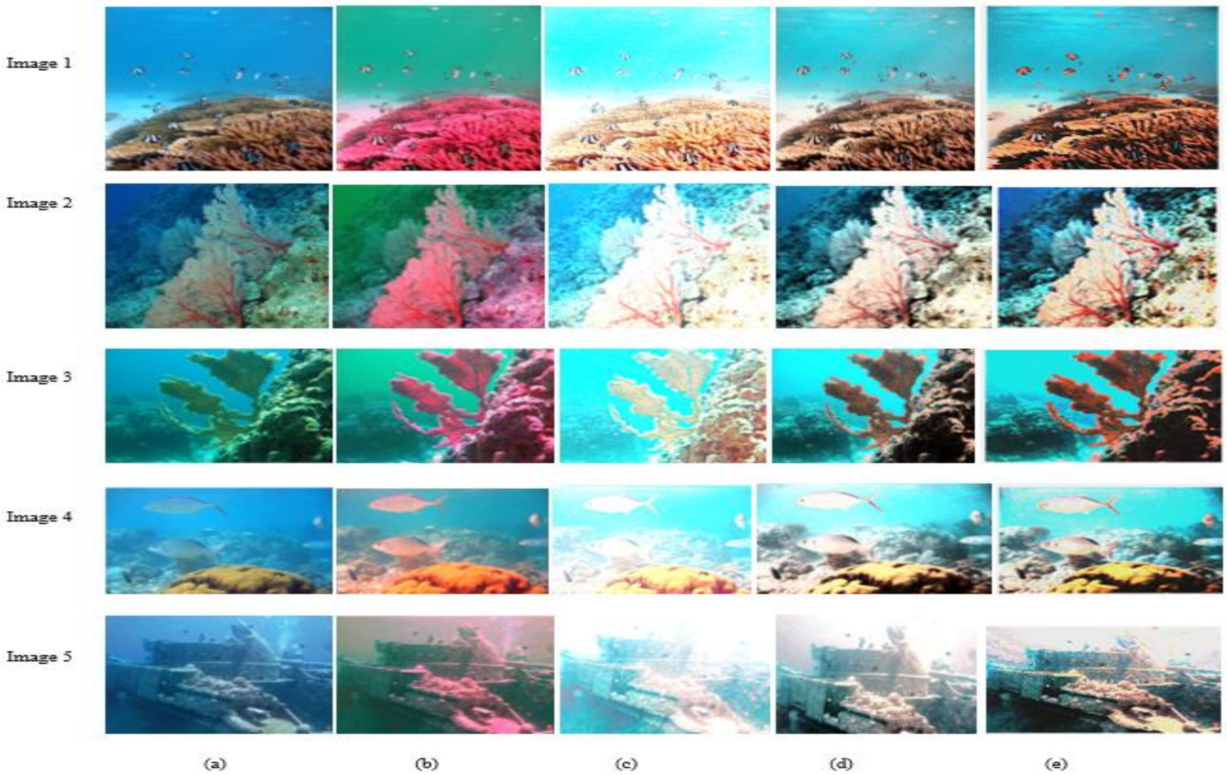

Figure 2 Visual Comparision Of Underwater Images (a) input images (b) enhanced images using gray world (c) enhanced images using adaptive gray world (d) enhanced images using AGW+DHE (e) enhanced images using naive fusion.

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