Weight Maps Guided Underwater Image Enhancement By Fusion Technique

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ABSTRACT

The underwater image plays a very important role in today's world in order to explore the unknown underwater world. But the images captured underwater are different from those taken in the air atmosphere. There are lots of problems associated such as haziness, blurriness, non-uniformity, color degradation, etc. All this is due to reflection, refraction, and scattering in water. To overcome these problems enhancement of the underwater image is required to get a better quality image. In this paper, the logarithmic image processing model is proposed as an important part of the methodology for underwater image enhancement. The insight to apply the logarithmic image processing model was taken from the human eye visual concept, as it functions in the logarithmic fashion while the camera functions linearly. A single image approach is used in which a degraded image is taken as an input and then various digital image operations are performed on it to enhance the quality of the underwater image. The insight to apply the logarithmic image processing model was taken from the human eye visual concept, as it functions in the logarithmic fashion while the camera functions linearly. The method is based on the fusion of directly derived images from gamma correction, sharpening, and their associated weight maps. Finally, the fused image is processed through Contrast Limited Adaptive Histogram Equalization (CLAHE) to get the enhanced output. The method is applied on two data set of images, subjective evaluation is computed and results are compared with other methods. To do an objective evaluation, the quality of output image measures through parameters and compared with other available methodologies. The experimental results show that the performance of the proposed method is competitive with that of available methods.

KEY WORDS: CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION (CLAHE), FUSION, HUMAN EYE VISUAL CONCEPT, LOGARITHM, UNDERWATER IMAGE ENHANCEMENT.

INTRODUCTION

The fundamental laws of light are different for underwater than the world outside the water. The underwater world has always fascinated humans by its beautiful oceanic beds, coral reefs, underwater spices, shipwreck, etc, and

has given rise to the curiosity of what lies within it. About 97% of the planet's water is an ocean and our planet earth satisfies the conditions for the living organism. To understand the underwater environment, its exploration is important, but due to the poor visibility and typical properties of water, it is very difficult to capture a clear underwater image. In underwater image enhancement, the properties of light penetration play an important role that is with every increasing depths there is a loss of color. Water absorbs different wavelengths of light and also scatters color at different degrees. The longest wavelength with the lowest energy gets absorbed first. The first color to get absorbed is red, followed by orange and yellow, the colors tend to disappear on the water in the same sequence as they appear in the color spectrum.

ARTICLE INFORMATION

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Received 14th Oct 2020 Accepted after revision 29nd Dec 2020

Print ISSN: 0974-6455 Online ISSN: 2321-4007 CODEN: BBRCBA

Thomson Reuters ISI Web of Science Clarivate Analytics USA and Crossref Indexed Journal

NAAS Journal Score 2020 (4.31)

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Online Contents Available at: <http://www.bbrc.in/>

Doi: <http://dx.doi.org/10.21786/bbrc/13.14/99>

Because of the disappearing of the colors at different depths, to find these colors in underwater is the most difficult challenge.

Enhancement methods used for underwater images takes image data without knowing or having environmental knowledge. Different enhancement techniques used for underwater image processing and analysis are mainly applied to natural images. They can be broadly categorized as filtering based method, color correction based method, and image fusion based method. The author Arnold-Bos proposed a pre-processing work for the luminance parameter of the underwater image. A method that has multiple filtering steps for the improvement of the non-uniform illumination, correction of color, noise suppression, contrast enhancement is discussed by author S. Bazeille . Adaptive total variation based on nonsubsampled contourlet transform for image denoising of underwater images is proposed by D. Jia .

To enhance the image contrast, stretching of color model based on the Rayleigh distribution is presented by A. S. A. Ghani. Integration of contrast stretched RGB color model and saturation & intensity stretched HSI color model is used to enhance the degraded images by K. Iqbal . An underwater image color correction method where objects are assigned color as fully saturated while water area as background assigned low saturation color concept is implemented by F. Petit . Retinex theory by E. H. Land correlates the reflectance of an object with the color of the object perceived in human eyes. A variational retinex model given by X. Fu discusses reflectance and illumination components of the image are enhanced separately and then the final enhanced image is obtained by combining both versions. The author S. Zhang highlights the combination of bilateral filter and trilateral filter which was utilized according to the characteristics of the color channels to get a better image. The white balancing process for the underwater image is explained by author C. O. Ancuti is faster by red channel attenuation.

The author Sophiya Philip in the paper shows the fusion of images which is used to combine the effect of sharpening, gamma correction, etc. This is a single image method and white balancing is used to reduce the blueish and greenish effect in the image. In this paper, an enhancement process is designed to increase the visual quality of degraded underwater images. The logarithmic image processing modeling step is added to keep the method near to the human eye visual system for the enhancement of the underwater images. Gamma correction and sharpening are applied to the white-balanced image. Then these images along with their weight maps are combined to get a fused image. Finally, the quality of this fused image is enhanced through Histogram equalization. The rest of the paper is organized as follows: Section II portrays the methodology, section III illustrates experimental results, and section IV conclusion.

METHODOLOGY

The input degraded image is taken, and logarithmic image processing is done and applied for white balancing. The white balancing helps in removing the unrealistic color cast. This white-balanced output is given to gamma correction and sharpening. Gamma correction is done to sync the image to the human eye of perception biasing it with luminance or say brightness of an image. It can also be said that it is a type of function which maps luminance levels to compensate for the non – linear luminance effect of displaying a screen. The same white-balanced input is given to the sharpening of the image, sharpening of an image is done to get the small details, and also for highlighting the edges. Then weight maps of both outputs of gamma correction and sharpening are computed. The weighted maps of gamma-corrected image and a sharpened image along with the output of the gamma image and sharpening image are fused to form a single image. Then the output multiscale fused image is given to CLAHE, this helps to improve the clarity of an image. The complete process is shown In Figure 1.

Figure 1: Flowchart of the Proposed Method

Logarithmic Image Processing Model: The input degraded image of underwater is taken for image enhancement then it is given to the logarithmic function to change the dynamic range of the image. Each pixel of the underwater image is replaced, it was observed that low-intensity pixel is enhanced which is useful for dynamic ranges that are too large. After applying log functions it is observed that log to the base 2 ($\log_2$) gives better results compared to the natural log function, so $\log_2$ is selected for image enhancement.

2 Weight Maps and Fusion: While using the weighted maps during fusion the weight maps with high values are contributed more to the final result. The weighted maps which are used in the fusion algorithm are Laplacian contrast weight (W_L), Saliency weight (W_s), and Saturation weight (W_{Sat}).

A) Laplacian contrast weight (W_L): Laplacian of an image is used for the regions having abrupt or rapid intensity change.

B) Saliency Weight Map(W_s): It is used for the objects which lose their visibility, appearance, or say prominence in underwater. A saliency weight map can be calculated by taking the absolute value of the difference between the mean luminance value of the image and the Gaussian blurred version of the luminance channel.

C) Saturation weight (W_{sat}): This weight map is computed as the deviation between color channels (R_k, G_k, B_k) and the luminance (Y_k) of the input.

$$W_{sat} = \{ 1/3((\bar{r}_k - \bar{y}_k)^2 + (\bar{g}_k - \bar{y}_k)^2 + (\bar{b}_k - \bar{y}_k)^2) \}^2 \quad (1)$$

Here $\bar{r}_k, \bar{g}_k, \bar{b}_k$ is the luminance component of the image in the $YCbCr$ model. Three weight maps are added W_l, W_s, W_{sat} to get the aggregate weight Map W_k , for each and every input k .

D) Multiscale Fusion Process: Multiscale fusion is the process of mixing the Gaussian pyramid and the Laplacian pyramid. Gaussian pyramid and the Laplacian pyramid can be calculated by using the following equation respectively.

$$G_k = G_l \{W_k(x)\} \quad (2)$$

$$L_k = L_l \{I_k(x)\} \quad (3)$$

$\{I_k(x)\}$ represents each source input, k is no. of input images, G_l is the l th level of the Gaussian pyramid and L_l is the l th level of Laplacian pyramid. Sl is the final output that can be obtained by adding the fuse contribution at all levels. Thus, Multi-scale fusion is very sensitive to the edges and sharp regions which are inspired by human visual systems. This gives better results to underwater image enhancement.

$$I_l(\bar{c}) = \sum_{k=1}^K \bar{c}_k \cdot \bar{c}_k \quad (4)$$

Experimental Results

A. Subjective Evaluation of Processes used for Enhancement: Log2 method was used to convert each pixel value of the degraded input image into logarithmic pixel values. Then white balancing is applied. Two inputs are derived after white balancing. The first derived input is obtained by applying Gamma correction to the input. The second derived input is capable of enhancing edges in the image and to get the small details through sharpening. Weight maps are calculated to avoid artifacts and compute the important features of the derived inputs. The resultant image is fused using derived inputs and weight maps. The fused image is then enhanced using CLAHE. Output images of all these processes are shown in Figure 2. The proposed methodology is tested on the following data sets :

1. Dataset 1: This data set is available at <http://puiqe.eecs.qmul.ac.uk/Dataset> and the data set is used by authors C. O. Ancuti and S. Emberton. We too have taken images from the ReefnFish dataset. Figure 3 shows the implementation of the proposed method

on three degraded input images.

2. Dataset 2: Another data set used for subjective evaluation for the proposed method is from author P. Drews and Wenhao Zhang. Figure 4 shows the visual comparison of the proposed method.

Figure 2: Output of the Proposed Method a) Degraded Input Image, b) Log 2 Image, c) White Balance Image, d) Gamma Image, e) Sharpening Image, f) Gamma Correction Weight Map Image, g) Sharpen Weight Map Image, h) Fused Image i) CLAHE Image

Figure 3: Each Pair of Resultant Images (a,b,c) shows a Degraded Image along with an Enhanced Image

Figure 4: Top Row: Three Raw Underwater Images. Middle Row: Enhancement by [16] Bottom Row: Result by the Proposed Method

Objective Evaluation: For objective assessment, the parameter used in Underwater Image Quality Measure (UIQM) were taken from following authors which are Risheng Liu, P. Sahotra and Chau Yi Li which comprises of three underwater image parameters viz, the Underwater Image Colourfulness Measure (UICM), the Underwater Image Sharpness Measure (UISM), and Underwater Image Contrast measure (UIConM). Table 1 shows the comparison of UIQM value with other methods and also other parameter values of an image.

Table 1. Comparison of UIQM (Underwater Image Quality Measure) Parameters and Detail Values of UIQM i.e Colorfulness, Sharpness, Contrast.

Method	Zhang	Fu	New-Optical	DCP	SID	HE-Lab	Proposed Method
UIQM	1.708	1.625	1.589	1.452	1.336	1.397	1.350882
UIQM value in detail							
UIQM = c1* UICM + c2* UISM + c3* UIConM							
Output image with the proposed method	Colourfulness (UICM)	Sharpness (UISM)	Contrast (UIConM)	UIQM			
	1.244726	0.240212	0.356067	1.350882			

$$UIQM = C_1 * UICM + C_2 * UISM + C_3 * UIConM \quad (5)$$

where C_1 , C_2 and C_3 are the scale factors having values as $C_1 = 0.0282$, $C_2 = 0.2953$ and $C_3 = 3.5753$.

CONCLUSION

Weight maps guided fusion technique for underwater image enhancement is implemented. The logarithmic image processing step is added to make the output comparable to the human visual system. The proposed method is implemented in two datasets. The experimental results of subjective and objective evaluations are observed and compared with other techniques. The parameters such as colorfulness, sharpness, contrast which are degraded in underwater due to forward and backward light scattering, are measured and finally, the value of UIQM is calculated. The calculated value of UIQM i.e. 1.350882 of an image taken, is between the values obtained from the HE-Lab method and the SID method.

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