International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-3, Issue-8, August 2015

Underwater Optical Image Dehazing Using Fast Guided Trigonometric Bilateral Filtering

Anshu R. Singh, Dr. R. G. Karandikar

Abstract— **This paper describes a novel method to enhance underwater optical images by dehazing. Scattering and color change are two major problems of distortion for underwater imaging. Scattering is caused by large suspended particles, like fog or turbid water which contains abundant particles, plankton etc. Color change corresponds to the varying degrees of attenuation encountered by light traveling in the water with different wavelengths, rendering ambient underwater environments dominated by a bluish tone. Our key contribution is to propose a fast image and video dehazing algorithm, to compensate the attenuation discrepancy along the propagation path, and to take the influence of the possible presence of an artificial lighting source into consideration. The enhanced images are characterized by reduced noised level, better exposedness of the dark regions, improved global contrast while the finest details and edges are enhance significantly. In addition, our enhancement method is comparable to higher quality than the state-of-the-art methods.**

Index Terms— **Image dehazing/defogging, Image Restoring, Image Enhancement**

I. INTRODUCTION

Underwater vehicles are used to survey the ocean floor, generally with optical sensors for their capability of remote sensing in recent years. Therefore, underwater vision is an important issue in ocean engineering. Different from the common images, underwater images suffer from poor visibility due to the medium scattering and light distortion. Because of the challenging environmental conditions and the differential light dissemination, most of traditional computer vision methods cannot be applied directly in underwater images [1].

First of all, capturing images underwater is difficult, mostly due to attenuation caused by light that is reflected from a surface and is deflected and scattered by particles, and absorption substantially reduces the light energy. The random attenuation of the light is mainly cause of the haze appearance while the fraction of the light scattered back from the water along the sight considerable degrades the scene contrast. In particular, the objects at a distance of more than 10 meters are almost indistinguishable while the colors are faded due to the characteristic wavelengths are cut according to the water depth [2].

There have been many techniques to restore and enhance the underwater images. Y.Y. Schechner et al. [3] exploited the polarization dehazing method to compensate for visibility degradation, using fusion method in turbid medium for reconstruct a clear image [4], combining point spread function and a modulation transfer function to reduce the blurring effect [5]. Although the aforementioned approaches can enhance the image contrast, these methods have demonstrated several drawbacks that reduce their practical applicability. First, the equipment of imaging is difficult in practice (e.g. range-gated laser imaging system). Second, multiple input images are required (e.g. two illumination images [4], white balanced image and color corrected image [2]).

In order to solve these two problems, single image dehazing method is mentioned. Fattal [16] firstly estimated the scene radiance and derived the transmission image by single image. However, this method cannot well process heavy haze images. Then, He et al. [17] proposed the scene depth information-based dark channel prior dehazing algorithm by using matting Laplacian, which could be computational intensive. To overcome this disadvantage, He et al. also proposed a new guided image filter [7] with the foggy image as a reference image, which lead to incomplete haze removal. Sun et al. [18] firstly considered combining bilateral filters with dark channel prior for haze or foggy removal. The computational time is $O(n^2/C)$, moreover, through the experimental results, there are some halos in the edges. Xiao et al. [19] extended this method and took a guided joint bilateral filter for dehazing. This method takes the median filtered image as a reference image for haze removal, and utilizes Yang's. [20] accelerate algorithm for speed up the computational time. These methods are based on a piecewise-linear approximation of bilateral filters, which could not well approximate the details of the image.

In this paper, we introduce a novel approach that is able to enhance underwater images based on single image, as well as colorization. We propose a new fast guided trigonometric filter instead of the matting Laplacian [6] or guided filters [7] to solve the alpha mattes more efficiently. In short summary, our technical contributions are in twofold: first, the proposed filter can perform as an edge -preserving smoothing operator like the popular bilateral filter, but has better behavior near the edges. Second, the novel guided filter has a fast and non-approximate constant-time algorithm, whose computational complexity is independent of the filtering kernel size.

II. UNDERWATER IMAGING MODEL

In the optical model, the acquired image can be modeled as being composed of two components. One is the direct transmission of light from the object, and the other is the

Anshu R. Singh,Department of Electronics & Telecommunication, K. J. Somaiya College of Engineering, Mumbai, India, 9869909361

Dr. R. G. Karandikar, Department of Electronics & Telecommunication, K. J. Somaiya College of Engineering, Mumbai, India, 9869218446

transmission due to scattering by the particles of the medium (e.g. airlight). Mathematically, it can be written as

$$I(x) = J(x)\,t(x) + \left(1 - t(x)\right)A \tag{1}$$

where I is the achieved image. J is the scene radiance or haze-free image, t is the transmission along the cone of vision, and $t(\mathbf{x}) = \exp(-\beta d(\mathbf{x}))$, β is the attenuation coefficient of the medium, $d(\mathbf{x})$ is the distance between the camera and the object, A is the veiling color constant and $\mathbf{x} = (x, y)$ is a pixel. The optical model assumes linear correlation between the reflected light and the distance between the object and observer.

The light propagation model is slightly different underwater environment. In the underwater model, absorption plays an important role in image degrading. Furthermore, unlike scattering, the absorption coefficient is different for each color channel, being the highest for red and lowest for blue in seawater. These leads to achieve the following simplified hazy image formation model:

$$I(x) = J(x)e^{-(\beta_s + \beta_r)d(x)} + \left(1 - e^{-\beta_s d(x)}\right)A \tag{2}$$

Where β_s is the scattering coefficient and β_a is the absorption coefficient of light. The effects of haze are highly correlated with the range of the underwater scene. In this paper, we simplify the situation as at a certain water depth, the transmission t is defined only by the distance between camera and scene.

III. GUIDED TRIGONOMETRIC BILATERAL FILTERING

The standard Gaussian bilateral filter is given as:

$$f'(x) = \frac{1}{\eta(x)} \int_\Omega G_{\sigma_s}(y) G_{\sigma_r}\left(f(x-y) - f(x)\right) f(x-y)\,dy \tag{3}$$

Where G_{σ_s} Gaussian spatial kernel and G_{σ_r} Gaussian range kernel and η is normalized coefficient

Assuming the intensity values $f(x)$ to be restricted to the interval [-T, T]. G_{σ_r} is approximate by raised cosine kernels. This is motivated by observation that, for al $-T \leqq s \leqq T$,

$$\lim_{N\to\infty} \left[\cos\left(\frac{rs}{\sqrt{n}}\right)\right]^N = exp\left(-\frac{r^2 s^2}{2\rho^2}\right) \tag{4}$$

The trigonometric function based bilateral filter [22] allows to express the otherwise non-linear transform in (8) as the superposition of Gaussian convolutions, applied on simple pointwise transforms of the image with a series of spatial filtering,

$$\left(F_0 * G_{\sigma_r}\right)(x), \left(F_1 * G_{\sigma_r}\right)(x), \ldots\ldots \left(F_N * G_{\sigma_r}\right)(x) \tag{5}$$

Where the image stack $F_0(x)$, $F_1(x)$,…, $F_N(x)$ are obtained from pointwise transform of $f(x)$. Each of these Gaussian filtering are computed using $O(1)$ algorithm. And the overall algorithm has $O(1)$ complexity.

IV. RECOVERING THE SCENE RADIANCE

With the transmission depth map, we can recover the scene radiance according to Equation (1). We restrict the transmission $t(x)$ to a lower bound t_0, which means that a small certain amount of haze are preserved in very dense haze regions. The final scene radiance $J(x)$ is written as,

$$J(x) = \frac{I_c(x) - A_c}{\max t(x), t_0)} + A_c \tag{6}$$

Typically, we choose t_0=0.1 in practice. We take color histogram processing for contrast enhancement.

V. EXPERIMENTAL RESULTS

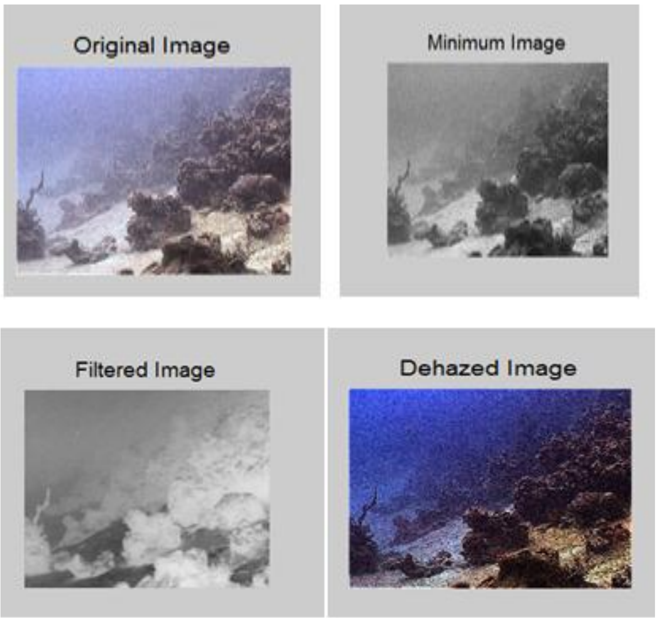
The performance of the proposed algorithm is evaluated both objectively and subjectively by utilizing ground-truth color patches. We also compare the proposed method with the state of the art methods. Both results demonstrate superior haze removing and color balancing capabilities of the proposed method over the others.

In the experiment, we take two groups of image from alpha matting website [9]. In the first test (natural image), we compare our method with Fattal and He's work. Here, we select patch radius r = 4, $\varepsilon = 0.1\times0.1$, in Windows XP, Intel Core 2 (2.0GHz) with 1 GB RAM. Figure 1 shows the results of different methods. The drawback of Fattal's method is elaborated on the Ref. [7]. To compare with He's method, our approach performs better. In He's approach, because of using soft matting, the visible mosaic artifacts are observed. Some of the regions are too dark (e.g. the center of the mountains image) and hazes are not removed (e.g. the sky of the image). There are also some halos around the stone. Our approach not only works well in haze removal, but also cost little computational complex. We also compare the results in test 2 (underwater image). We choose the patch radius $r = 8$, $\varepsilon = 0.2\times0.2$ for computing. The results are shown in Figure 2. The results also demonstrate that our proposed method is the best.

Coral reef's

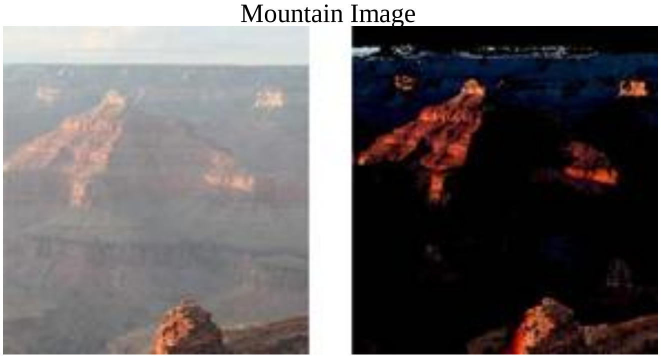
(a) Input Image (b) Fattal method

(c) He's Method (d) Huimin Method

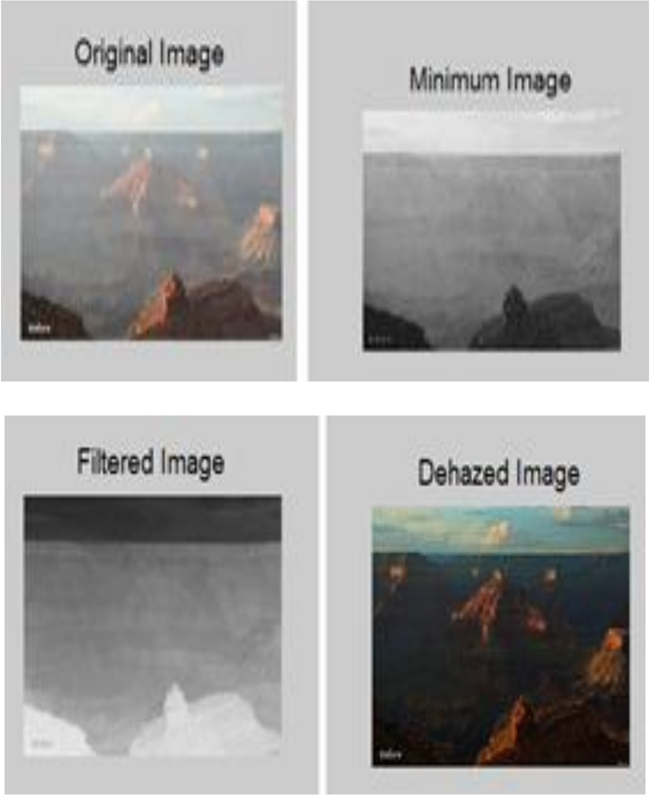


(e) Our proposed Method

Mountain Image



(a) Input Image (b) Fattal method



(e) Our proposed Method

Table I: Results of Various Methods

Image	Quantitative Analysis	
	Method	CPU time(s)
Coral Reef	Fattal Method	20.05
	He's Method	30.85
	Huimin Lu Method	4.42
	Our Proposed Method	1.37
Submarine	Fattal Method	20.23
	He's Method	30.75
	Huimin Lu Method	6.12
	Our Proposed Method	0.68
Mountain	Fattal Method	19.65
	He's Method	29.61
	Huimin Lu Method	5.72
	Our Proposed Method	0.81

VI. CONCLUSION

In this paper we explored and successfully implemented a novel image dehazing techniques for underwater images. We proposed a simple prior based on the difference in attenuation among the different color channels, which inspire us to estimate the transmission depth map. Another contribution is to compensate the attenuation discrepancy along the propagation path, and to take the influence of the possible presence of an artificial lighting source into consideration. After these, our algorithm is faster than the state of the art algorithms. That is suitable for real -time computing in practice.

REFERANCES

[1] C. Ancuti, C.O. Ancuti, T. Haber, P. Bekaert, “Enhancing Underwater Images and Videos by Fusion”, In Proceeding of IEEE Conference on Computer Vision and Pattern Recognition, pp.81-88, 2012.

[2] Y.Y. Schechner, Y. Averbuch, “Regularized Image Recovery in Scattering Media”, IEEE Transactions on Pattern Analysis & Machine Intelligence, vol.29, no.9, pp.1655-1660, 2007.

[3] T. Treibitz, Y.Y. Schechner, “Turbid Scene Enhancement Using Multi-Directional Illumination Fusion”, IEEE Transactions on Image Processing, July 16, 2012, http://www.ncbi.nlm.nih.gov /pubmed/22829404.

[4] W. Hou, D.J. Gray, A.D. Weidemann, G.R. Fournier, J.L. Forand, “Automated Underwater Image Restoration and Retrieval of Related Optical Properties”, In Proceeding of IEEE Internation Symposium of Geoscience and Remote Sensing, pp.1889-1892, 2007.

[5] A. Levin, D. Lishinski, Y. Weiss, “A Closed-form Solution to Natural Image Matting”, IEEE Transactions on Pattern Analysis & Machine Intelligence, vol.30, no.2, pp.228-242, 2008.

[6] K. He, J. Sun, X. Tang, “Guided Image Filtering”, In Proceeding of the 11th European Conference on Computer Vision, vol.1, pp.1-14, 2010.

[7] S. Paris, F. Durand, “A Fast Approximation of the Bilateral Filter using a Signal Processing Approach”, International Journal of Computer Vision, vol.81, no.1, pp.24-52, 2009.

[8] Alpha Matting Website. http://www.alphamatting.com

[9] Z. Wang, H.R. Sheikh, A.C. Bovik, “No-reference Perceptual Quality Assessment of JPEG Compressed Images”, In Proceeding of 2002 International Conference on Image Processing, vol.1, pp.477-480, 2002.

[10] R. Mantiuk, K.J. Kim, A.G. Rempel, W. Heidrich, “HDR-VDP2: A Calibrated Visual Metric for Visibility and Quality Predictions in All Luminance Conditions”, ACM Transactions on Graphics, vol.30, no.4, pp.40-52, 2011.

[11] H. Lu, L. Zhang, S. Serikawa, “Maximum Local Energy: An Effective Approach for Image Fusion in Beyond Wavelet Transform Domain”, Computers & Mathematics with Applications, vol.64, no.5, pp.996-1003, 2012.

[12] C. Ancuti, C.O. Ancuti, T. Haber, P. Bekaert, “Enhancing Underwater Images by Fusion”, In Proceeding of ACM SIGGRAPH2011, Article No.32, 2011.
[13] M.E. Munichi, P. Pirjanian, E.D. Bernardo, L. Goncalves, et al., “SIFT-ing Through Features with ViPR: Application of Visual Pattern Recognition to Robotics and Automation”, IEEE Robotics and Automation Magazine, vol.13, no.3, pp.72-77, 2006.
[14] M.A. Fischler, R.C. Bolles, “Random Sample Consensus: A Paradigm for Model Fitting with Applications to Image Analysis and Automated Cartography”, Communications of the ACM, vol.24, no.6, pp.381-395, 1981.
[15] R. Fattal, “Signal Image Dehazing”, In: SIGGRAPH, pp.1-9, 2008.
[16] K. He, J. Sun, X. Tang, “Single Image Haze Removal Using Dark Channel Prior”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol.33, no.12, pp.2341-2353, 2011.

Anshu R. Singh, Post-Graduate Student , Electronics & Telecommunications Engineering, K. J. Somaiya College of Engineering, Mumbai.

Dr. R. G. Krandikar, Dean(EXTC) Electronics & Telecommunications Engineering,K. J. Somaiya College of Engineering, Mumbai.