IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 33-36

Survey: Underwater Image Visibility Restoration Techniques

Mr. Mithun M. Patil, Mr. Vishwajit B. Gaikwad
(Department of Computer Engineering, TEC, Nerul
(Department of Computer Engineering, TEC, Nerul

Abstract: *Under water image enhancement has been a topic of scope since last few decades. Several attempts have been made by various researchers and organizations to improve the accuracy and thereby enhance the visibility of underwater images. Normal images which are taken outside water in open environment have sufficient light to capture the scene and hence they have good visibility. However under the water light propagation is affected mainly due to absorption thereby reducing light energy and scattering effect caused by moving water which causes change in direction of light propagation. Another major factor that added noise to underwater image is turbidity of water. To handle such situations and restore the visibility of underwater images, a lot of work has been carried out in past. Number of methods such as statistical models, histogram equalization, exposure analysis and single or multi-image restoration approach has been proposed. This survey article studies such methods and techniques for underwater image enhancement.*
Keywords: *Image fusion, underwater image, histogram equalization*

I. Introduction

Underwater imaging has applications in various areas such as adventure photography, study of marine creatures, scientific research, rescue operations and control of watercraft. It plays a major role in management and maintenance of man-made infrastructure laid underwater such communication network links, pipelines and bridges.

Various technology advances have been introduced in recent past that allows us to capture images and videos under water. Using waterproof cameras, people can capture memory while scuba diving, visiting underwater parks and adventure games underwater.

When light hits water surface, some portion is reflected reverse and other enters the water vertically. Further, as light passes deeper in water its energy starts decreasing due to absorption. This not only causes reduction in the quantity of light signal but also starts dropping off different colors depending on the color wavelength. For example, first at the depth of 3m red color gets disappeared then orange color at 5m depth and yellow at the depth of 10m. Finally green and purple colors disappear as light passes further [1].

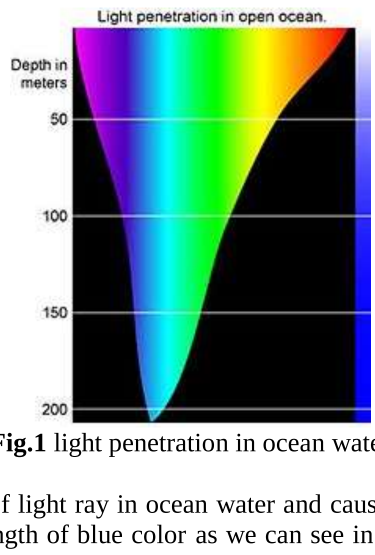

Fig.1 light penetration in ocean water

Fig.1 illustrates penetration of light ray in ocean water and causing individual colors to shade off as it goes deeper. Due to the short wavelength of blue color as we can see in Fig. 2, it travels deeper into the water making underwater images bluish. This causes images to appear foggy with degraded brightness and contrast.

Color	Wavelength (nm)
Red	780 - 622
Orange	622 - 597
Yellow	597 - 577
Green	577 - 492
Blue	492 - 455
Violet	455 - 390

Fig.2 0043olor wavelength in nanometers

Even though there exists many image enhancing techniques such as white balance, histogram equalization and color correction, they cannot be fully utilized as the underwater images have different physical properties than images taken outside water. This triggers demand for more sophisticated methods for handling underwater images.

II. Literature survey

This section reviews related work that have been done for processing and restoring the visibility of underwater images. In 2011 Hung-Yu Yang; Pei-Yin Chen; Chien-Chuan Huang; Ya-Zhu Zhuang; Yeu-Horng Shiau,[2] proposed "Low Complexity Underwater Image Enhancement Based on Dark Channel Prior,". The proposed method is based on dark channel prior which is a one of the widely used de-hazing technique. It employs median filter for analyzing image and estimating its depth map. The advantage of using median filter over the soft matting algorithm is it requires less number of iterations for optimization process thereby reducing the computing resources needed, but it doesn't work efficiently when amount of impulse noise is more. Subsequently method of color correction is applied for better visibility of objects in underwater image. The proposed method claimed to be real-time and enhance visibility with reduced execution time.

In 2013 M. Hitam; W. Yussof; E. Awalludin; Z. Bachok, [3] researched on "Mixture contrast limited adaptive histogram equalization for underwater image enhancement,". It utilizes the modified technique of histogram equalization for improving visuals of underwater image. The working principle of histogram equalization method is to map each pixel to an intensity value based on surrounding pixels. Drawback of basic method is it is slow and sometimes increases the contrast of noise present in image producing undesirable effects. Modified versions such as adaptive histogram equalization (AHE) [4] and contrast limited adaptive histogram equalization (CLAHE) [3] were proposed to overcome this issue by working on different regions of image rather than working on entire image. However they could not solve the problem efficiently. The proposed method named mixture contrast limited adaptive histogram equalization (CLAHE-Mix). Original CLAHE technique can operate on both RGB and HSV models. CLAHE-HSV restores visual sense more efficiently that CLAHE-RGB, however images looks unnatural. To reduce this unnatural effect, the proposed method joins the results of CLAHE-RGB and CLAHE-HSV using Euclidean norm. The results were tested both subjectively and objectively. In objective evaluation, mean square error (MSE) and peak signal to noise ratio (PSNR) metrics used to assess efficiency of restored underwater images. The results show improved visibility with low MSE and high PSNR.

In 2016 Xiaopeng Liu; Guoqiang Zhong; Cong Liu; Junyu Dong, [5] researched on "Underwater image color constancy based on DSNMF". Wavelength of light is generally altered as it passes through deep water mainly due to turbidity, depth and water movement making captured scene blurred. The proposed method named deep sparse non-negative matrix factorization (DSNMF) [5] is designed to measure illumination of different patches of an underwater image. Initially source image is divided into distinct patches and expressed as an [R, G, B] matrix and then using grey image (GI) and estimated illumination matrix (R_{illum}, G_{illum}, B_{illum}) calculated using DSNMF [5], the visibility of image under examination is improved. The performance is evaluated using color root mean enhancement (CRME) [6] and an underwater color image quality evaluation metric (UCIQE) [7]. The results illustrates under no use of any other image for reference the proposed method is effective and simple to implement.

In January 2018 Codruta O. Ancuti; Cosmin Ancuti; Christophe De Vleeschouwer; Philippe Bekaert, [8] researched on "Color Balance and Fusion for Underwater Image Enhancement". The proposed method requires only single image and does not require any additional information. The original underwater image is first white-balanced, which is then processed using Gamma correction and edge sharpening [8] independently deriving two intermediate images. Finally resultant images are fused using multi-scale method of image fusion. Multiple images and videos taken underwater using various devices and professional photographers were tested using proposed method. Images processes were having 8-bit data format [8] as the case with most of the cameras commonly in use. The method is evaluated using UCIQE [7], PCQI [9], and UIQM [10]. PCQI is focuses on image contrast metric. UCIQE and UIQM are specifically designed metrics for underwater image assessment. UCIQE metric quantifies three characteristics of underwater images namely non-uniform color cast, blurring, and low-contrast. UIQM addresses colorfulness, sharpness and contrast.

In June 2018 Kohei Nomura; Daisuke Sugimura; Takayuki Hamamoto, [11] proposed "Underwater Image Color Correction using Exposure-Bracketing Imaging". As light passes under deep sea water it starts causing severe color distortion. Due to larger wavelength, red component of light ray diminish sooner compared to other components. The proposed method intends to restore lost information using estimated grey information. The technique used is exposure-bracketing imaging [11] which acquires several images of same scene at different times with varying exposure level. It ensures sufficient information about red channel is gathered. Initially multiple images of scene are captured using exposure-bracketing imaging [11]. Then image shot at long-exposure is taken to obtain red component information and that with short-exposure to obtain green and blue component information. These selected images are fused into single image. To correct misalignment, it uses dense adaptive self-correlation descriptor (DASC) [12]. Grey information of resultant image is extracted and outliers are removed using truncation parameter. Finally color correction is performed by applying linear regression method to grey information.

Table.1 Comparison of various methods of underwater enhancement

Year	Author	Title	Method	Outcome	Limitations
2011	Hung-Yu Yang; Pei-Yin Chen; Chien-Chuan Huang; Ya-Zhu Zhuang; Yeu-HorngShiau	Low Complexity Underwater Image Enhancement Based on Dark Channel Prior	Dark Channel Method	Efficient contrast and color correction Suitable for real-time applications	Not efficient for more noisy images
2013	M. Hitam; W. Yussof; E. Awalludin; Z. Bachok	Mixture contrast limited adaptive histogram equalization for underwater image enhancement	CLAHE-Mix	Restores natural look with reduced noise Efficient color correction using RGB and HSV	Doesn't consider image sharpness
2016	Xiaopeng Liu; GuoqiangZhong; Cong Liu; Junyu Dong	Underwater image colour constancy based on DSNMF	Deep sparse NMF	Improved RGB illumination without any reference information	Higher computational cost
2018	Codruta O. Ancuti; CosminAncuti; Christophe De Vleeschouwer; Philippe Bekaert	Color Balance and Fusion for Underwater Image Enhancement	Multi-scale image fusion	Improved global contrast Easy to use single-image approach	Applicable to only 8-bit data format Not effective haze removal
2018	Kohei Nomura; Daisuke Sugimura; Takayuki Hamamoto	Underwater Image Color Correction using Exposure-Bracketing Imaging	Exposure-Bracketing Imaging, image fusion and color correction	Efficient RGB color correction.	Does not enhance contrast and sharpness

III. Problem statement

Underwater imaging has applications in several fields of research and study. However processing these images is highly challenging task. Underwater images suffer from poor visibility resulting from the attenuation of the propagated light mainly due to absorption and scattering effects. The absorption substantially reduces the light energy, while the scattering causes changes in the light propagation direction. As a consequence captured visuals suffer foggy appearance and contrast degradation.

Many researchers have attempted in past to process such degraded underwater images in order to restore their natural visual appearance. In some of the previous works, the problem has been tackled by using specialized hardware and polarization filters. These methods provide significantly improvement, however they suffer from a number of issues such as equipment cost, processing time which reduces their practical applicability. Other group of researchers proposed single or multiple image methods using combination of statistical and fusion techniques. The results shows better efficiency both in terms of visual appearance as well as processing time needed. However they suffer from poor edges, amplified noise and unnatural look. Therefore there is a need of an efficient method which can restore natural visuals of images captured under deep sea with conventional hardware and in near-real time.

IV. Proposed method

To further enhance the accuracy and restore visibility of underwater images existing work can be extended. Proposed method initially acquires multi-exposure underwater images using high dynamic range (HDR) imaging. Traditional imaging, like LDR, is unable to store and display high-contrast scenes. This is because common LDR formats, like JPEG, PNG, don't contain enough information to reproduce brightness, contrast, and sharpness of original scene. This can be overcome using high fidelity HDR techniques.

Further color correction can be done by using multi-scale fusion [8] and followed by HDR contrast enhancement operation to improve the brightness quality of the output image. Using this approach proposed method is expected to accurately restore the natural look of the scene.

Proposed method can be summarized as:

1. Take multiple HDR images at different exposure time.
2. Use long-exposure image for extracting red component and relatively short ones for extracting blue and green component.
3. Use Fourier method for adjusting misalignment.
4. Fuse resultant images using multi-scale fusion.
5. Apply HDR contrast enhancement operation to enhance global image contrast.

V. Conclusion

This review paper studied various factors affecting visibility of underwater images such as light absorption, scattering and attenuation. It has reviewed various techniques of underwater image enhancement using multiple approaches used for color correction, contrast enhancement, noise removal and visual pleasure.

It reviewed depth estimation using dark channel prior followed by color correction to improve the image contrast and reduce undesired noise. Studied single and multi-image approaches for recovering lost features of images degraded due to extreme conditions under water. It has reviewed technique of recovering shaded colors, especially red component, to restore original visuals of underwater images. It also illustrated contrast enhancement matrix factorization and CLAHE-Mix to restore natural look of the scene.

Finally limitations of existing methods are discussed and need in future to extend existing work to invent optimal techniques for restoring more sharper, natural and accurate images.

References

[1]. L. Torres-Mendez and G. Dudek, Color Correction of Underwater Images for Aquatic Robot Inspection, *Springer, pp. 60-73*, 2005.

[2]. H. Yang, P. Chen, C. Huang and Y. Zhuang, Low Complexity Underwater Image Enhancement Based on Dark Channel Prior, *Innovations in Bio-inspired Computing and Applications (IBICA)*, Shenzhan China, 2011.

[3]. M. Hitam, W. Yussof, E. Awalludin, Z. Bachok, Mixture contrast limited adaptive histogram equalization for underwater image enhancement, *International Conference on Computer Applications Technology* , Sousse Tunisia, 2013.

[4]. S. Pizer, E. Amburn, J. Austin, R. Cromartie, A. Geselowitz, T. Greer, B. Romeny, J. Zimmerman and K. Zuiderveld, "Adaptive Histogram Equalization and Its Variations", *Computer Vision, Graphics, and Image Processing 39*, 1987, 355–368.

[5]. X. Liu, G. Zhong, C. Liu and J. Dong, Underwater image colour constancy based on DSNMF, *IET Image Processing, VOL. 11(1),* 2017, 38-43.

[6]. K. Panetta, C. Gao and S. Agaian, No reference color image contrast and quality measures', *IEEE Trans. Consumer Electronics, VOL. 59(3),* 2013, 643–651.

[7]. M. Yang and A. Sowmya, An underwater color image quality evaluation metric, *IEEE Transaction on Image Processing, VOL. 24(12)*, 2015, 6062–6071.

[8]. C. Ancuti, Cosmin Ancuti, C. Vleeschouwer, and P. Bekaert, Color Balance and Fusion for Underwater Image Enhancement, *IEEE TRANSACTIONS ON IMAGE PROCESSING*, VOL. 27(1), 2017, 379-393.

[9]. S. Wang, K. Ma, H. Yeganeh, Z. Wang, and W. Lin, "A patch-structure representation method for quality assessment of contrast changed images," *IEEE Signal Processing Lett*er, *vol. 22(12),* 2015, 2387–2390.

[10]. K. Panetta, C. Gao, and S. Agaian, Human-visual-system-inspired underwater image quality measures, *IEEE J. Ocean. Eng., vol. 41(3)*, 2015, 541–551.

[11]. K. Nomura, D. Sugimura and T. Hamamoto, Underwater Image Color Correction using Exposure-Bracketing Imaging, *IEEE signal processing letters, VOL. 25(6)*, 2018, 893-897.

[12]. S. Kim, D. Min, B. Ham, M. N. Do, and K. Sohn, DASC: Robust dense descriptor for multi-modal and multi-spectral correspondence estimation, *IEEE Transactions on Pattern Analysis and Machine Intelligence, VOL. 39(9),* 2017, 1712–1729.