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by Pujiono Pujiono

COLOR ENHANCEMENT OF UNDERWATER CORAL REEF IMAGES USING CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION (CLAHE) WITH RAYLEIGH DISTRIBUTION

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ABSTRACT

Nowadays there is a big challenge on conducting a research on underwater image resulted from light absorbed by sea water and scattered light by tiny underwater particles by using camera. One of the disadvantages of camera is its limited visibility distance, which reaches only a few meters under the sea surface. This obstacle causes a bad image quality. This research proposes a method to enhance underwater image quality by using Contrast Limited Adaptive Histogram Equalization (CLAHE) with uniform distribution, Rayleigh distribution, and exponential distribution. Underwater image quality is measured by using Mean Square Error (MSE). The result shows that CLAHE with uniform distribution gives better result if used with small MSE than CLAHE with Rayleigh or exponential distribution, in which MSE for red, green, and blue are 992.38, 649.76, and 613.98 respectively.

Keywords: *Image Enhancement, Underwater Image Processing, CLAHE, MSE*

1. INTRODUCTION

The beauty, uniqueness, and variety of underwater life in Indonesian archipelago have a lot of potentials, both economically and ecologically. One of these potentials is coral reef resource. Indonesia is a country having 18% of coral reef worldwide, and now this number is given much attention as 5.23% of it is in bad condition. It is said that now Indonesia's coral reef is threatened with extinction according to The reef at risk and Indoensia institute of science [1][2].

The data of coral reef were taken from Karimunjawa, a group of islands in Jepara regency, Central Java, Indonesia. The width of its land is ±1.500 ha and its water is ±110.000 ha. The archipelago consists of 27 islands, 5 of which are inhabited: Karimunjawa as the main island, Kemujan, Parang, Genting and Nyamuk. The archipelago is included as conservation area by the Ministry of Forestry [3].

There is a challenge on conducting research on underwater image. The image quality degrades because of light absorbing process and light distribution. Some studies have been conducted to enhance underwater image [4][5][6][7][8].

Fig. 1. Karimunjava's Coral Reefs

Reflection polarization of light penetrates horizontally and vertically because of light absorption. Vertical polarization enables an object to capture color depth and it becomes shinier [9].

Seawater is 800 times denser than air, and it becomes the main obstacle in underwater imaging. The seawater density gives effect on water surface, light moving from the air to the water, turning into bright and sharp light (see Figure 2) [9]. The light penetrating the water decreases gradually as it gets deeper in the water, therefore creating a dark underwater image.

Based on [4], there are two kinds of underwater imaging. First is image restoration and second is image enhancement. Enhancement method does not require knowledge such as attenuation coefficient, scatter coefficient, and object estimation so this method is simpler than image restoration.

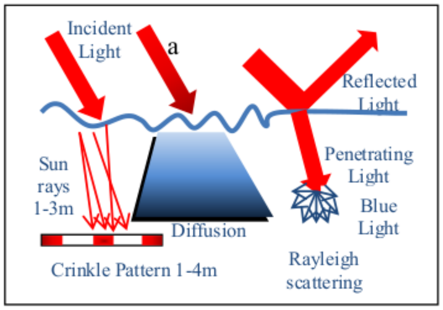


Fig. 2. Water surface effects [9]

Padmavathi et al [6] propose 3 filtering image: anisotropic diffusion, homographic filter and wavlet denoising with filter average to enhance image quality. From those three filters, wavelet denoising gives expected result in Mean Square Error (MSE) and Peak Signal Noise Ratio (PSNR).

Singh et al [7] compared enhancement contrast and conducted underwater image analysis. Mean Square Error (MSE) was used to evaluate contrast enhancement performance.

Iqbal et al [4] propose underwater image enhancement by using integrated color model. They offer two approaches, namely contrast stretching of algorithm RGB to balance image color contrast and Intensity Saturation and Stretching from Hue Saturation Intensity (HIS) used to enhance real color and solve lighting problems.

Iqbal et al [8] offer Unsupervised Color Correction Method (UCM) approach to improve underwater image. This approach can efficiently remove bluish color and enhance color of red; and low illumination and underwater true color. Other studies on underwater image quality enhancement can be found in [10][11][12].

Several enhancement methods are used to enhance the quality of an image which includes gray scale manipulation, filtering and Histogram Equalization (HE) [13]. Histogram Equalization is one of the popular technique for contrast enhancement because this method is simple and effective [13]. Contrast Limited Adaptive Histogram Equalization (CLAHE) has becoming successful histogram equalization method for low contrast image enhancement [14].

2. THEORETICAL FRAMEWORK

This section outlines several related and supporting theories. They are Contrast stretching and Contrast Limited Adaptive Histogram Equalization (CLAHE).

2.1 Contrast Stretching

Contrast stretching is a technique to enhance image contrast with intensity value range [15]. Contrast stretching of every pixel is calculated by using (1)

$$P_{out} = (P_{in} - c)\frac{(b-a)}{(d-c)} + a \qquad (1)$$

where P_{out} is the normalized pixel value, is the considered pixel value, a is the lower pixel value, b is the upper pixel value, c is the lowest pixel value currently present in the image, d is the highest pixel value currently present in the image [16]

2.2 A Contrast Limited Adaptive Histogram Equalization

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a improved version of Adaptive Histogram Equalization (AHE) in which noise problem in AHE can be reduced by limiting contrast enhancement especially in homogenous area. It is characterized by a peak of histogram related to contextual area as many pixels are joined in the same gray range. Contrast Limited Adaptive Histogram Equalization (CLAHE) is used to enhance image contrast by changing intensity value in the image

CLAHE operates in a small area called tile. CLAHE applies bilinear interpolation to eliminate region boundaries; therefore small neighboring areas look smoother (as if no boundaries). the advantage of using CLAHE is that it is easy to use, uses simple calculation, and give good output in most part of the image. CLAHE has less noise and it can prevent brightness saturation that commonly happens in Histogram Equalization. Histogram pixel can be Rayleigh distribution, uniform distribution, and exponential distribution [17].

The clip limit β can be obtained by :

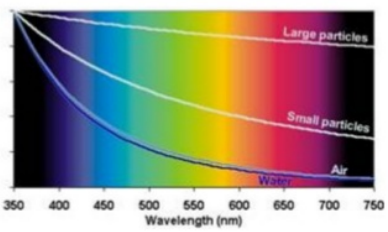
$$\beta = \frac{M}{N}\left(1 + \frac{\alpha}{100}\left((S_{\max} - 1)\right)\right) \quad (2)$$

Where α is clip limit factor, M region size, N is grayscale value. The maximum clip limit is obtained for $\alpha = 100$

The grayness of uniform distribution has flat data distribution whereas grayness level of exponential distribution is dispersed with higher frequency. the grayness of Rayleigh distribution is dispersed in the middle, on grayish level.

2.3 Rayleigh Distribution

In molecular scattering the light interacts with air or water molecules, which are tiny compared to the wavelength of the light. Molecular scattering has two characteristics. First, short wavelengths (violet and blue) are scattered much more than longer wavelengths (Fig. 3). Second, the light is scattered more or less equally in all directions.



Fiq. 3. Wavelength dependences of scattering

The size of a scattering particle is parameterized by the ratio x of its characteristic dimension r and wavelength λ :

$$x = \frac{2\pi r}{\lambda} \quad (3)$$

Rayleigh scattering can be defined as scattering in the small size parameter regime x ≪ 1. Scattering from larger spherical particles is explained by the Mie theory for an arbitrary size parameter x. For small x the Mie theory reduces to the Rayleigh approximation.

The amount of Rayleigh scattering that occurs for a beam of light depends upon the size of the particles and the wavelength of the light.

The intensity I of light scattered by a single small particle from a beam of unpolarized light of wavelength λ and intensity I_0 is given by :

$$I = I_0 \frac{1+\cos^2\theta}{2R^2}\left(\frac{2\pi}{\lambda}\right)^4\left(\frac{n^2-1}{n^2+2}\right)^2\left(\frac{d}{2}\right)^6 \quad (4)$$

where R is the distance to the particle, θ is the scattering angle, n is the refractive index of the particle, and d is the diameter of the particle. The Rayleigh scattering cross-section is given by :

$$\sigma_s = \frac{2\pi^5}{3}\frac{d^6}{\lambda^4}\left(\frac{n^2-1}{n^2+2}\right)^2 \quad (5)$$

The Rayleigh scattering coefficient for a group of scattering particles is the number of particles per unit volume N times the cross-section. As with all wave effects, for incoherent scattering the scattered powers add arithmetically, while for coherent scattering, such as if the particles are very near each other, the fields add arithmetically and the sum must be squared to obtain the total scattered power.

3. EXPERIMENT

In this experiment the data were taken from Karimunjawa islands, Jepara regency, Central Java, Indonesia. Images were taken by using three pairs of Olympus Tough-8010 cameras with 1280X720 pixels resolution [18]. The cameras were installed in a stereo frame as shown in Figure 4, while data acquisition is shown in Figure 5.

Fig. 4 Low Cost Multi-View Camera Installation

Fig. 5. Data Acquisition

The framework testing of image qulity enhancement is done by choosing 50 pairs of image. Image enhancement is done by using exponential contrast stretching, CLAHE with uniform distribution and CLAHE with Rayleigh distribution.

4. RESULTS

The experiment of enhancing underwater image quality enhancement by using the aforementioned methods and measuring image quality through Mean Square Error (MSE) results in the following:

The color red, green, and blue which use CLAHE with uniform method has smaller MSE values compared to those using CLAHE with Rayleigh and exponential methods (Figure 6, 7, 8). The Mean Square Error (MSE) value of red, green, and blue which use CLAHE Uniform, CLAHE Rayleigh and exponential is shown in Figure 9. The comparison of underwater image before and after enhancement using contrast stretching, CLAHE with uniform distribution, and CLAHE with Rayleigh distribution is shown in Figure 10.

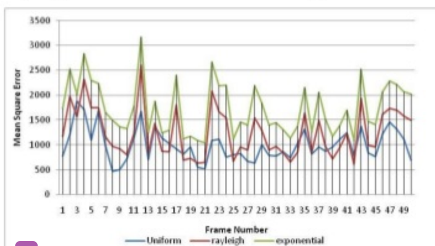


Fig. 6. Mean Square Error of Red Using CLAHE Uniform, Rayleigh, and Exponential Methods

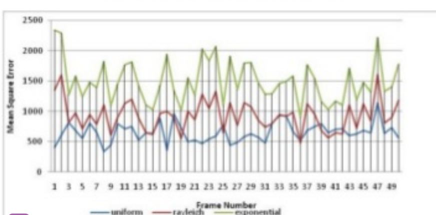


Fig. 7. Mean Square Error of Green Using CLAHE Uniform, Rayleigh, and Exponential Methods

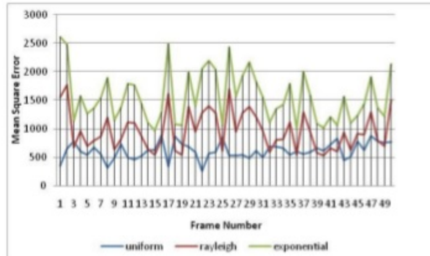


Figure 8 Mean Square Error Green Using CLAHE Uniform, Rayleigh, and Exponential Methods

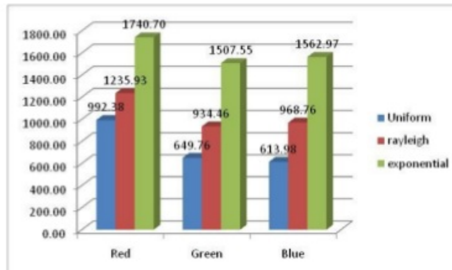


Fig. 9. MSE Average of RGB Using CLAHE Uniform, Rayleigh, and Exponential Methods

5. CONCLUSION AND FUTURE WORK

This research describes underwater image color enhancement by using exponential contrast stretching, CLAHE Uniform and CLAHE Rayleigh distribution. The experiments show that CLAHE with uniform method has smaller value of Mean Square Error than CLAHE with Rayleigh and exponential methods, in which the Mean Square Error for red, green, and blue are 992.38, 649.76, and 613.98 respectively.

It is suggested that the future researchers interested in similar topic use different methods to obtain a better underwater image quality.

REFERENCES

1. C Beall, B J Lawrence, V Ila, and F Dellaert, *Reconstruction 3D Underwater Structures.*: Atlantic, 2010
2. Abdullah Habibi, Naneng Setiasih, and Jensi Sartin, "A Decade of Reef Check Monitoring: Indonesian Coral Reefs, Condition and Trends," The Indonesian Reef Check Network , 2007.

3. G. Diansyah, T.Z. Ulqodry, M. Rasyid, and A. Djawanas, "The Measurements of Calcification Rates in Reef Corals Using Radioisotope 45 Ca at Pongok Sea, South Bangka," *Atom Indonesia Journal*, vol. 37, no. 1, pp. 11-16, 2011

4. K. Iqbal, R. A. Salam, A. Osman, and A. Z. Talib, "Underwater Image Enhancement Using an Integrated Colour Model," *IAENG International Journal of Computer Science*, Vol. 34, No. 2, 2007.

5. A. Mahiddine, J. Seinturier, J. M. Boï, and P. Drap D. Merad, "Performances Analysis of Underwater Image Preprocessing Techniques on the Repeatability of SIFT and SURF Descriptors," in *WSCG 2012: 20th International Conference on Computer Graphics, Visualization and Computer Vision*, 2012.

6. P. Subashini, M. M. Kumar, S. K. Thakur, and G. Padmavathi, "Comparison of Filters used for Underwater Image Pre-Processing," *International Journal of Computer Science and Network Security*, vol. 10, no. 1, pp. 58-65, 2010.

7. B. Singh, R. S. Mishra, and P. Gour, "Analysis of Contrast Enhancement Techniques For Underwater Image," *International Journal of Computer Technology and Electronics Engineering*, pp. pp. 190-194., Vol. 1, Issue 2, October 2011.

8. K. Iqbal, M. Odetayo, A. James, and R. Abdul Salam, "Enhancing The Low Quality Images Using Unsupervised Colour Correction Method," in *IEEE International Conference on Systems Man and Cybernetics (SMC)*, 2010.

9. J Floor Anthoni. (2005) [Online]. http://www.seafriends.org.nz/phgraph/water.htm

10. Y. Swirsk, Y.Y Schechner, B Herzberg, and S. Negahdaripour, "Stereo from flickering caustics," in *Computer Vision, 2009 IEEE 12th International Conference on*, 2009, pp. 205-212.

11. C. Doutre and P. Nasiopoulos, "Correcting Sharpness Variations in Stereo Image Pairs," in *CVMP '09 Proceedings of the 2009 Conference for Visual Media Production*, 2009, pp. 45-51.

12. Taekyung Kim and Joonki Paik, "Adaptive Contrast Enhancement Using Gain-Controllable Clipped Histogram Equalization," *IEEE Transactions on Consumer Electronics*, vol. 54, no. 4, Nov. 2008

13. Rajesh Garg, Bhawna Mittal, and Sheetal Garg, " Histogram Equalization Techniques For Image Enhancement,"*IJECT*, vol.2, no. 1, 2011.

14. Puran Gour, Balvant Singh Rajesh Kumar Rai, " Underwater Image Seqmentation Using CLAHE Enhancement and Tresholding," *International Journal of Emerging Techonolgy and Advanced Engineering*, vol.2,no. 1, January 2012.

15. Al Bovik, *Handbook of Image and Video Processing*. London, United Kingdom: Academic Press, 2000

16. R. Fisher, S. Perkins, A. Walker, and E. Wolfart. (2003) "Contrast Stretching". [Online]. http://homepages.inf.ed.ac.uk/rbf/HIPR2/stretch.htm

17. Celia Freitas da Cruz, "Automatic Analysis of Mammography Images: Enhancement and Segmentation Technique," Master in Bioengineering, Porto University, 2011.

18. P. N. Andono, E. M. Yuniarno, M. Hariadi, and V. Venus, "3D Reconstruction of Under Water Coral Reef Images Using Low Cost Multi-View Cameras," in *Proceedings of International Conference on Multimedia Computing and Systems (ICMCS)*, May 10-12, 2012, pp. pp. 803-808.

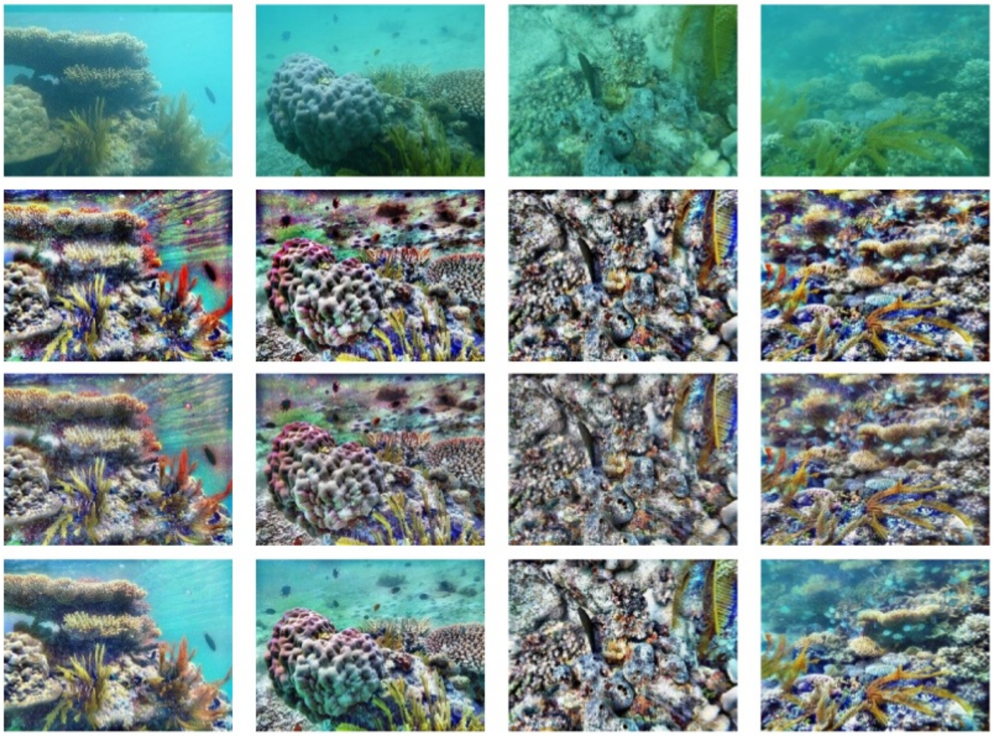


Figure 10. Comparison of image quality before and after enhancement. **First Row.** before enhancement. **Second Row.** enhancement using CLAHE with exponential distribution. **Third Row.** enhancement using CLAHE with Rayleigh distribution. **Fourth Row.** enhancement using CLAHE with uniform distribution.

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