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Underwater Coral Reef Color Image Enhancement Based on Polynomial Equation

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Abstract – *Eighteen percent of the world's coral reefs are located in Indonesia. Currently, thirty percent of coral reefs in Indonesia are in poor condition. One indication of a healthy coral reef is given by its color. However, there is a difficulty in identifying the original color of a coral reef. When a coral reef is taken out of water, the color becomes different from its original color. This paper proposes a polynomial equation approach to enhance the color of a coral reef by returning the constancy of the basic colors of Red, Green, and Blue (RGB). The quality of color enhancement result is measured by using Peak Signal to Noise Ratio (PSNR). Furthermore, by applying polynomial equation the average value of Peak Signal to Noise Ratio is 33.94, meaning that the color of coral reef is visually enhanced. It can be concluded that polynomial equation can be used to enhance underwater coral reef color image.* ***Copyright © 2016 Praise Worthy Prize S.r.l. - All rights reserved.***

Keywords*: Underwater Coral Reef, Image Color Enhancement, Polynomial Equation*

Nomenclature

a_n	Coefficient of the n^{th} constan function
k	Depth of k below water surface
$K(k)$	A constant function in form of polynomial of n degree at depth k
I_k	Image color intensity at depth$k$ below water surface
I_p	Image color intensity on the water surface
I_{kb}	Images color intensity in depth k for blue
I_{kg}	Images color intensity in depth$k$ for green
I_{kr}	Images color intensity in depth k for red
I_{pb}	Images color intensity on the water surface for blue
I_{pg}	Images color intensity on the water surface for green
I_{pr}	Images color intensity on the water surface for red

I. Introduction

The beauty, exceptionality, and diversity of underwater life in Indonesia's archipelago have a lot of mysteries and potentials. One of these potentials, the natural resource, with a high economical and ecological value, is coral reef resource. Indonesia is a country that has 18% of coral reefs worldwide. However, the world is now giving much attention as 30% of the coral reefs in Indonesia are in poor condition, this condition leads Indonesia's coral reef to be threatened [1].

Some efforts to preserve coral reefs as parts of Indonesia's natural resources need to be done. Currently, 30% of coral reefs are in poor condition.

The health of a coral reef can be seen from its color. One main problem to obtain the original color of a coral reef is that when it is taken out of water, the color changes due to the different environment, i.e. underwater and land [2]. The current observation by marine scientists is conducted by a video camera [3].

They use color, texture, and structure to classify and identify a coral reef, but the color change makes difficult for them to observe the coral reef [3], [4].Two main sources of distortion of underwater color image are color change and light scattering: these two sources may introduce contrast loss and color deviation in the acquired underwater images [5].

Nowadays, there has been no technique with the ability to process an accurate underwater image quality due to color change and light scattering [5]. In this paper a new approach in image enhancement of underwater color image based on polynomial equation is proposed.

II. Related Works

Andono, P.N., et al.[2] stated that the quality of underwater image has a high influence in image registration. A method of image registration is the scale-invariant feature transform (SIFT).

The use of Contrast Limited Adaptive Histogram Equalization (CLAHE) of Rayleigh distribution to enhance underwater image color improves the scale-invariant feature transform (SIFT)registration to 41%, compared to the use of Contrast Stretching. The underwater image enhancement by using Contrast Limited Adaptive Histogram Equalization (CLAHE) is

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better than using Contrast Stretching. Yussof, W.N.J.H.W., Hitam, M.S., Awalludin, E.A. and Bachok, Z [3] conducted a research to enhance underwater image by using Contrast Limited Adaptive Histogram Equalization (CLAHE). The combination method of Contrast Limited Adaptive Histogram Equalization (CLAHE) applied to RGB and HSV color models is able to enhance the result of underwater image effectively.

The image quality enhancement is measured by using Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) which results in low MSE value and high PNSR value. Beohar, R. and Sahu P. [4] found difficulties in analyzing the details of underwater objects,mainly because of the low quality of image brightness. The use of Contrast Limited Adaptive Histogram Equalization (CLAHE) method with 2D filter median can enhance and equalize the image contrast and underwater image contrast histogram effectively.

Chiang, J.Y., and Chen, Y.C. [5] proposed the use of Wavelength Compensation and Image Dehazing (WCID) algorithm. This algorithm is able to restore the balance of underwater image effectively, although up to now there hasn't been the best technique to handle two main underwater image distortion sources in underwater image, i.e. light scattering and color change.

Chiang, J.Y., Chen, Y.C., and Chen, Y.F [6], Proposed an algorithm to restore underwater images that combines a dehazing algorithm with wavelength compensation (WCID) to address distortion from color scatter and color cast. The WCID algorithm can be used to restore image color and toremove haze effectively.

According to Iqbal K, Salam RA. Osman A, and Talib AZ [7],the low underwater image quality due to degradation by light absorption and scattering causes one color to dominate the others.

Two approaches are conducted: first, contrast stretching with RGB to equalize the contrast color in the image; second, using saturation and intensity of HIS to enhance underwater image color and solving lighting problem. The results of both approaches are that the underwater image quality is statistically improved through histogram.

Iqbal K, Odetayo M, James A, Salam RA and Talib AZ[8], proposed an unsupervised color correction method to enhance the low quality images. Several problems in underwater image are due to lighting and color change. The Unsupervised Color Correction Method (UCM) approach is based on color balance, RGB color and its color contrasts. The underwater image obtained from this approach is more efficient since it is able to enhance image color so thatthe image color is as its original one. Karam, G. S., Abood, Z. M, and Saleh, R. N. [9] suggested the technique of enhancing underwater image quality by combining classical contrast enhancement dengan fuzzy histogram equalization. Fuzzy Histogram Equalization technique results in better spread and itincreases theunderwater image contrast.

The research conducted by Hitam, M.S., Yussof, W.N.J.H.W, Awalludin, E.A., Bachok, Z [10] on Contrast Limited Adaptive Histogram Equalization (CLAHE) is based on RGB and HSV color models and combines it with euclidean norm. This method is effectively able to enhance the visibility of underwater image quality. Meanwhile, the underwater image quality is measured by using Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) which results in higher PSNR value and lower MSE value.

Padmavathi, G, Subashini, P., Kumar, M. M., and Thakur, S.K. [11]used three filters to improve the quality of underwater image, namely anisotropic diffusion, homomorphic filter, and wavelet denoising by average filter. Among the three filters, wavelet denoising by average filter gives the best Peak Signal to Noise Ratio (PSNR) and Mean Square Errror (MSE) results.

bt Shamsuddin, N. et al. [12] conducted a research enhancement and auto correction techniques. Manual enhancement technique has a higher precision level than auto correction technique. However, both techniques have significant influence to underwater image enhancement.

SwarnaLakshmi R.and Loganathan B. [13],proposeda color constancy algorithm based approach. The aim of this approach is to capture image characteristics and parameter features and to optimize image color constancy. The proposed color constancy algorithm approach is tested on a synthetic image and the result is as good as the real image.

According to Sukmaaji, A. et al [14], one of the causes of low underwater image quality is lighting. Scattered lighting or flicker is caused by sea water surface and irregular wave. Flicker on underwater image causes different image interpretation, thus it needs to be removed from the image. Sukmaaji et al also proposed an approach for modifying HSV color model. HSV color model improves the image repeatedly until the flicker is eliminated. The experiment was conducted by taking 20 out of 2000 images randomly by using HSV color model. Flicker was removed after 5 times of iteration, thus the method effectively remove the flicker

Rai, R.k., et al. [15] found that the low contrast of underwater image and light propagation are the main obstacles in segmenting underwater image. They proposed theunderwater image segmentation method enhancing the image quality by using Contrast Limited Adaptive Histogram Equalization (CLAHE) and segmenting objects by using histogram thresholding technique. CLAHE is not only able to improve contrast but italso equalizes the image histogram efficiently.

According to Singh, B. et al. [16], enhancing underwater image can also be done by enhancing its features. Low visibility level, resolution, and contrast of the underwater image become the main challenge. Their paper proposed contrast stretching, histogram equalization, and contrast limited adaptive histogram equalization approach. The performance of this approach was measured by using mean squuare error and SNR, in which CLAHE approach is more effective to enhance underwater image contrast and visibility.

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Kaur, E.C. et al. [17] suggested a way to to identify the characteristics of underwater objects for enhancing the underwater image quality. Ordinary histogram equalization uses the same transformation derived from the image histogram to transform all thepixels.

The purpose is to enhance underwater image contrast and to maintain brightness level. This approach was tested in several underwater images and itgave better image quality and PSNR value.

Jayasudha, F.V.et al. [18], proposed a fuzzy c-means approach to increase image color underwater, where the initial process uses medial filtering algorithm for removing noise and for classifying the RGB channel.

The clustering results by using Fuzzy C-Means (FCM) were measured using the MSE and SNR produced better results than with OSGFB methods.

III. Materials and method

III.1. Data Acquisition Location

Coral reef location as the source of data in this research was in Karimunjawa island in the northern part of Java island, Indonesia. The island is located at 5°49'-5°57' South Latitude and 110°04' - 110°40'East Longitude in the Java Sea, north of Java, Indonesia (see Fig. 1). The biodiversity level of the area around the Karimunjawa islands is among the highest, based on the decision of the Minister of Forestry, and it was declared a nature conservation area [2].

Coral reef images were captured using Olympus Tough-8010 camera with a resolution of 1280 × 720 pixels. The image acquisition procedure was performed at a depth of 5 meters below the water surface as shown in Fig. 2.

III.2. Polynomial Equation

The polynomial equation is an approach to determine the constancy of basic colors of Red, Green and Blue (RGB) in underwater images.

Fig. 1. Karimunjawa Island, Central Java, Indonesia

Fig. 2. Data Acquisition

The approach has two steps: first, determining the constant function of the relationship between color intensity on the surface and in certain depth; second, determining the constant function coefficient by using least square. The general form of model polynomial equation approach in the underwater image can be written as follows:

$$I_p = I_k \cdot K(k) \quad (1)$$

$$K(k) = a_0 + a_1 k + a_2 k^2 + \ldots + a_n k^n \quad (2)$$

where I_p, I_k are images color intensity on the water surface and color intensity in k depth respectively, whereas $K(k)$ is a constant function in form of polynomial of n degree at depth$k$at a depth of 5 meters below the water surface.

Images of a sample object containing six different colors were taken under the water surface in 1 meter, 2 meter, 3 meter,4 meter and 5 meter depth respectively (Figs. 3). The image of an object containing basic color of red, green and blue, (Fig. 4) was also captured.

The image is used to determine the average intensity value of red, green and blue color (Table I).

TABLE I
THE VALUE OF RGB COLOR INTENSITY IN EACH DEPTH

Depth	Color		
(Meters)	Red	Green	Blue
0	254.38	226.57	199.08
1	72.04	126.51	116.79
2	47.8	160.39	140.64
3	78.86	162.81	143.51
4	115.91	204.36	180.93
5	83.37	200.73	177.94

By applying Eqs. (1) and (2) in Table I, the following equations can be obtained:

$$I_{pr} = I_{kr}\,(-11.23 + 25.30k - 12.92k^2 + \\ +2.55k^3 - 0.17k^4\,) \quad (3)$$

$$I_{pg} = I_{kg}(4.33 - 4.52k + 2.52k^2 + \\ -0.60k^3 + 0.05k^4) \quad (4)$$

$$I_{pb} = I_{kb}(3.86 - 3.89k + 2.23k^2 + \\ -0.54k^3 + 0.05k^4) \quad (5)$$

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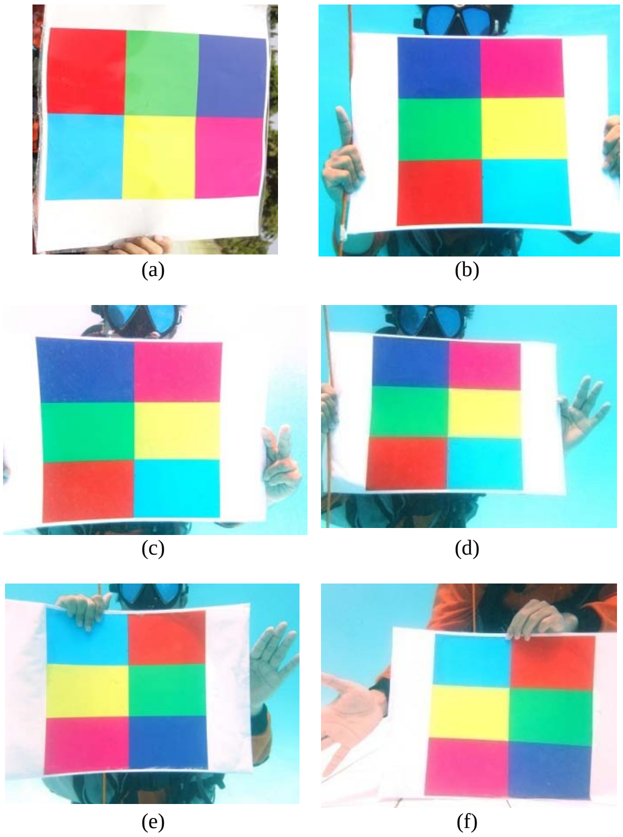


Figs. 3. (a) water surface, (b) 1 m depth, (c) 2 m depth, (d) 3 m depth (e) 4 m depth, and (f) 5 m depth

Fig. 4. Color Samples

Given that I_{pr}, I_{pg}, I_{pb} are image color intensity on the water surface for red, green and blue respectively, whereas I_{kr}, I_{kg}, I_{kb} are color intensity in k depth for red, green and blue respectively.

Eqs. (3), (4) and (5) are polynomial approach to enhance image color based on the constancy of red, green and blue. If the color intensity of red, green and blue in k depth is identified, then the color intensity of red, green, and blue on the water surface can be determined.

The intensity of red, green and blue is the color basic of an image. If the color image in k depth is identified, by using a polynomial equation approach then the color image on the water surface can be determined.

The intensity of red, green and blue in k depth highly influences the constancy of red, green, and blue on the water surface.

III.3. Evaluation Procedure

Performance testing approach polynomial equation for underwater image enhancement is done by comparing the approach of polynomial equation with Histogram Equalization [9], [19], [20], and Contrast Limited Adaptive Histogram Equalization (CLAHE)[2]-[4], [15].

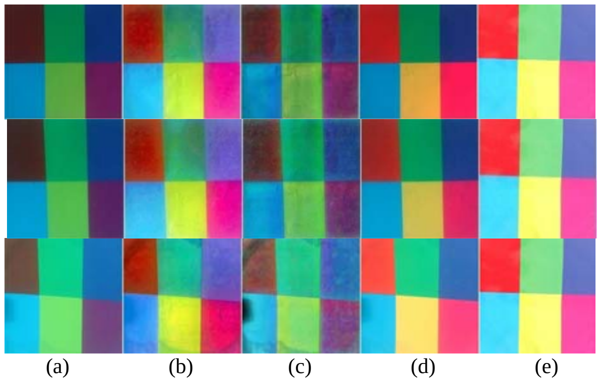
Measurement of the quality of the image result are done by using Peak Signal To Noise Ratio [10], [11].

The measurement of image quality with the Peak Signal to Noise Ratio gives an average value of PSNR for approaching polynomial equation, Histogram Equalization (HE) and Contrast Limited Adaptive Histogram Equalization (CLAHE) is 20.41, 17.93 and 16.19 respectively, see Table II. The larger the value of Peak Signal to Noise Ratio (PSNR) is then the better the image quality will be [10], [11].

TABLE II
PEAK SIGNAL TO NOISE RATIO

Depth (m)	Before	After Using		
		PE	HE	CLAHE
1	13.61	21.05	18.61	14.69
2	16.15	21.63	18.46	16.49
3	14.59	19.76	18.27	15.36
4	17.79	19.57	16.97	17.33
5	18.09	20.05	17.36	17.09

Visually, the color quality of the image produced by the polynomial equation approach approximates the color image on the surface (the original color) as in Figs. 5.



Figs. 5. (a) Underwater color image , (b) Color image enhancement using Histogram Equalization (HE), (c) Color image enhancement using CLAHE, (d) Color image enhancement using Polynomial Equation (PE), and (e) Color image on the water surface

IV. Experimental and Results

The images were extracted from video file obtained with the data acquisition procedure. One of the images is shown in Figs. 6.

IV.1. Underwater Coral Reef Color Image Enhancement Based on Polynomial Equation

Fifty samples of coral reef images were enhanced by using Polynomial Equation.

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(a)

(b)

Figs. 6. Image extraction (a). coral reef images
(b). Fish and Coral reef image

The quality of enhancement result was measured by using Peak Signal to Noise Ratio (PSNR. The result shows that the average value of Peak Signal to Noise Ratio (PSNR) for red is 12.69, green45.93, and blue43.19. The average value of Peak Signal to Noise Ratio by using Polynomial Equation approach is greater than that using Histogram Equalization (HE) or Contrast Limited Adaptive Histogram Equalization (CLAHE), as seen in Table III and Fig. 7.

Figs. 8 present the histogram graph where underwater image for the red channel is the dark area then using a polynomial approach the red color is improved and most of the red color in the lighter areas, while green and blue color enhancement is relatively small compared to an increase in the brightness of red. This is because at a depth 5 meters below the water surface all red color is absorbed while green and blue colors are forwarded, so that the deeper under the surface water, green and blue colors dominate [3][10].

TABLE III
PEAK SIGNAL TO NOISE RATIO OF RGB

Method	Red	Green	Blue
Histogram Equalization	17.85	21.12	21.40
CLAHE	18.39	20.14	20.38
Polynomial Equation	12.69	45.93	43.19

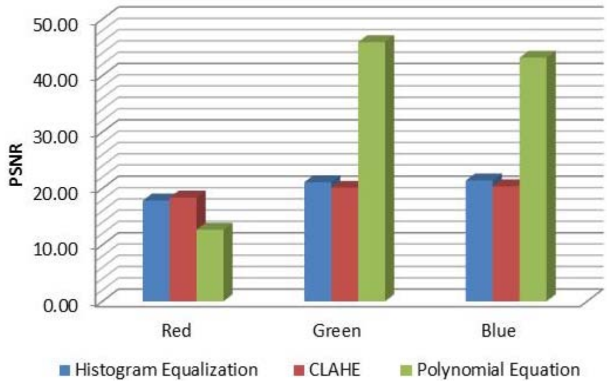
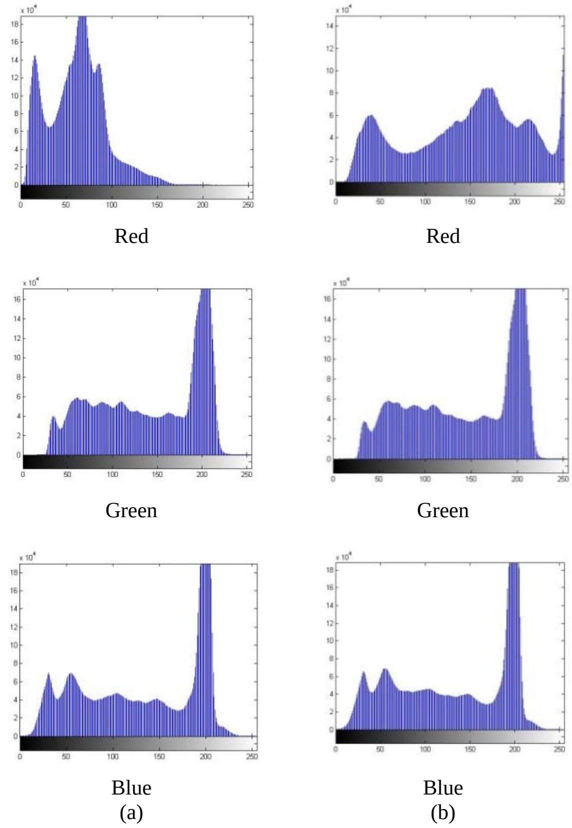


Fig. 7. Peak Signal to Noise Ratio of RGB



Figs. 8. Histogram graph for underwater image (a). before using polynomial equation (b). after using polynomial equation

Visually, the result of enhancement by using polynomial equation is better as seen in Figs. 9.

The enhancement result is measured by using Peak Signal to Noise Ratio (PSNR).

The PSNR values for Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE), and Polynomial Equation (PE) methods are shown in Fig. 10.

This figure reveals that the PSNR value obtained from Polynomial Equation (PE) is greater than that obtained from Contrast Limited Adaptive Histogram Equalization (CLAHE).

It can be said that the greater PSNR value is, the better the enhanced image quality [10] [11] will be.

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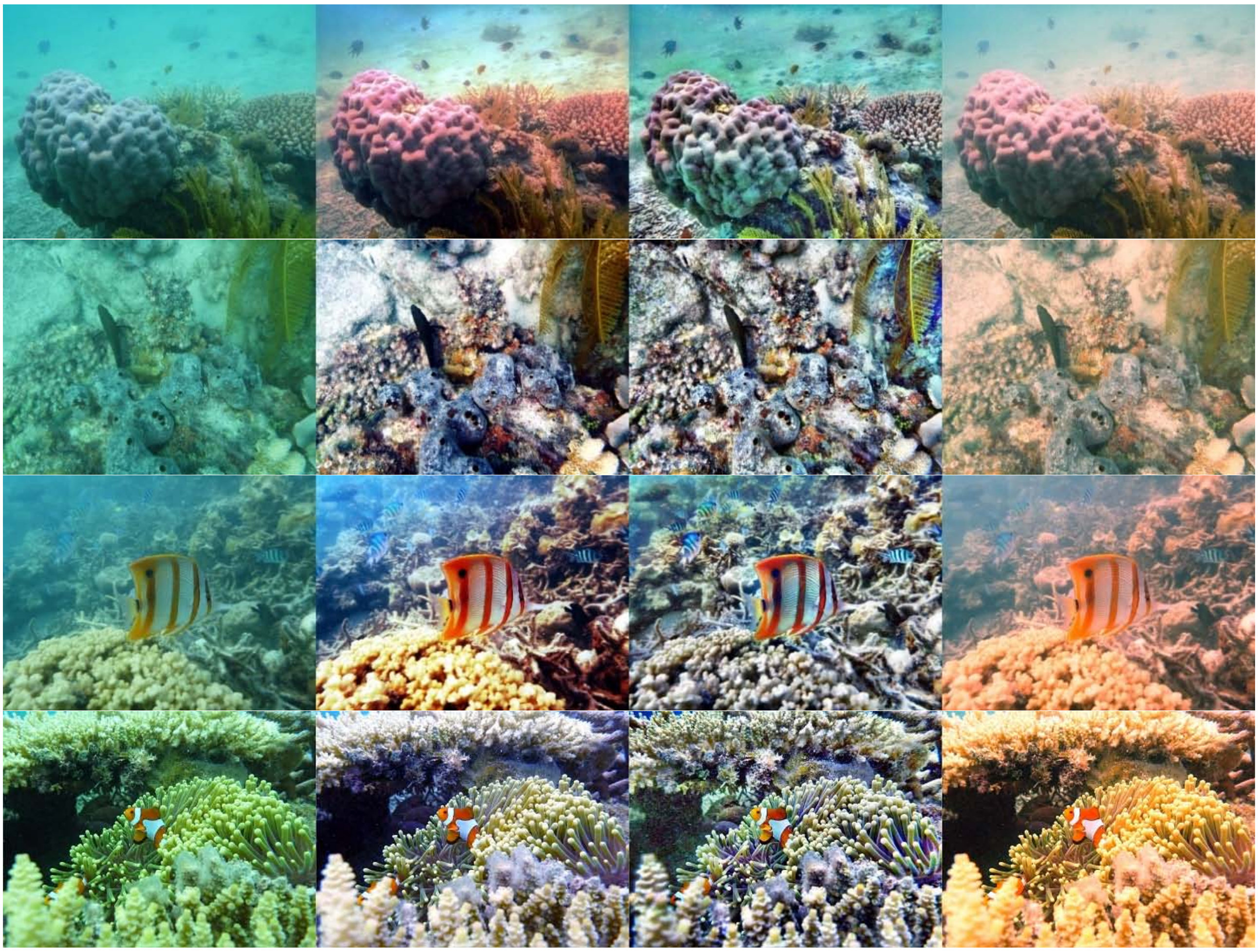

Figs. 9. (a). Coral Reef underwater (b). Coral reef color enhancement using Histogram Equalization (c) Coral Reef color enhancement using CLAHE, (d). Coral Reef color enhancement Using Polynomial Equation

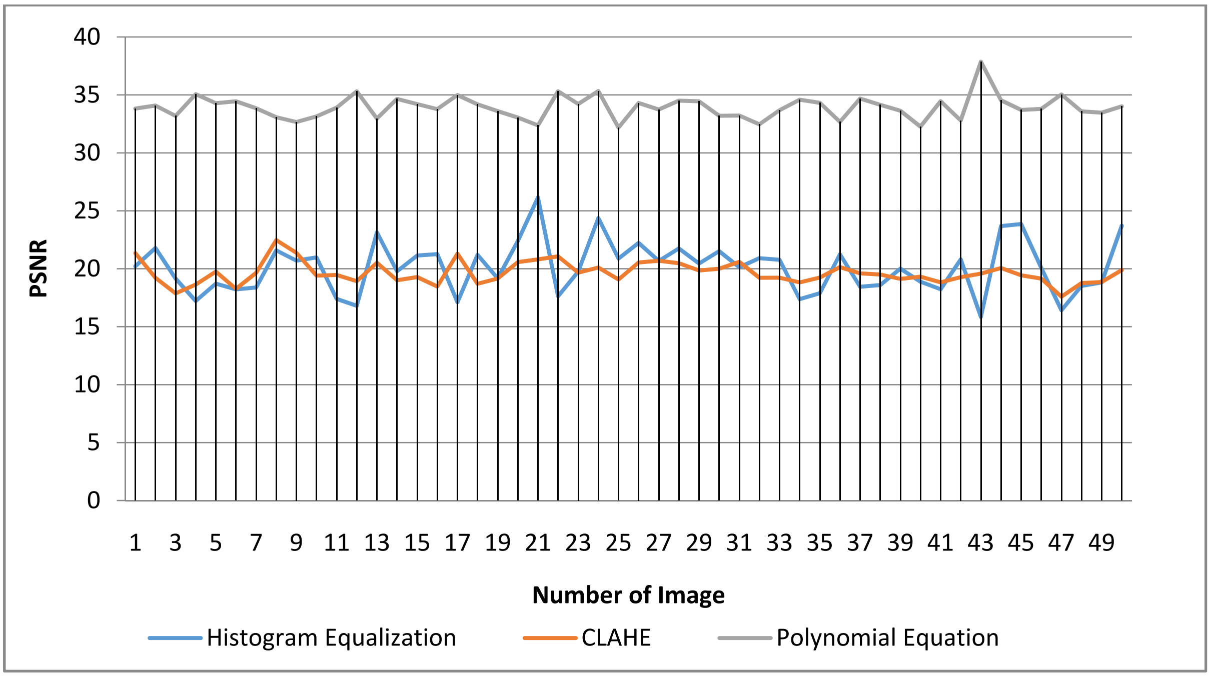

Fig. 10. Peak Signal to Noise Ratio by using HE, CLAHE, and PE methods

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V. Conclusion

This paper has presented the approach to enhance coral reef color image based on Polynomial Equation.

The polynomial equation used in the research aims to restore the constancy of the basic colors of red, green and blue (RGB).The quality of the enhancement is measured by using Peak Signal to Noise Ratio (PSNR) method. In the proposed experiment, the PSNR obtained had a value of 33.94 meaning that visually the coral reef image color is improved. It can be concluded that the proposed approach based on polynomial equation can be used to enhance underwater color coral reef. For future research, this study suggests that the quality of coral reef image in 5 m depth below the water surface will be enhanced by using approaches having a better accuracy.

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