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Underwater Image Enhancement Using Histogram Equalization and Color Correction

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Abstract: This research provides instructions for improve underwater image quality using histogram equalization and color correction. Images processing plays important role, the image does not only provide effects that make an image better but also must be able to improve quality of the image itself. The performance of each method is calculated by finding the Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR).

Keywords: underwater images, image enhancement, histogram equalization, color correction, MSE, PSNR.

1. INTRODUCTION

Underwater images is an underwater photo-taking process and is performed not only by SCUBA (Self-Contained Underwater Breathing Apparatus) but can also be done with a camera that dives underwater and is operated from the surface. The results of the documentation obtained are not as clear when compared to the documentation obtained on the mainland. There are several factors that affect the quality of underwater imagery. First, the absorption of light in water and the spread of light that alters the flow of light by small particles in the environment in the water have a limited impact on visibility during shooting. Second, the absorption and scattering effect is not only caused by the water itself but also for other components such as dissolved organic matter or small observable floating particles. The visibility range can be improved by artificial lighting but due to these absorption and scattering factors, artificial lighting tends to illuminate objects in a less uniform way, resulting in bright spots in the center of the image and poor lighting around them. This absorption and spread affects the seven color elements that sunlight has. The seven color elements of sunlight have different abilities in penetrating water. Purple and blue wavelengths are the most efficient in the spread of light. Therefore, if documentation is done in deeper waters then what is obtained is a blue color that increasingly dominates[2]. This is why it is necessary to improve the quality of underwater images.

Image processing can be utilized to improve the quality of underwater images. Several studies have been conducted to improve underwater images, such as researchers[3] stating that the use of gamma correction can improve dark image. The goal is to process an image so that the result is more suitable than the original image to be applied to a more specialized application. Researchers [4] analyzed systems that could perform underwater images improvements by applying RGB-HSI color model stretching methods and homomorphic filtering. The results showed optimum values in PSNR and MSE, depending on the combination of parameters. The selection of underwater image repair methods should be considered for accuracy in order to know the maximum results of the study. As in digital image repair research using Histogram Equalization (HE)[5]. The use of the method is one of the very effective techniques used in improving the entire detail of imagery and texture. The histogram equalization method is also one of the most efficient techniques for reducing missmatch between training results and test data results. The study [6] mentions the use of histogram equalization methods is considered easy due to simplicity and has relatively better performance in almost all types of images and is also able to increase images contrast. The method used by [7] for color correction in underwater images using Markov Random Field (MRF) increases color, contrast, and brightness of underwater images. The advantage of the MRF method is that it only requires a small set of patch images to color and correct images with depleted colors.

2. METHOD

2.1 Input Image

The initial process of this application is process the underwater images into the program. The image data used is an underwater image with RGB level with .jpg format. Image resolution size used is 500x300 pixels. The underwater image will be shown in Figure. 1.

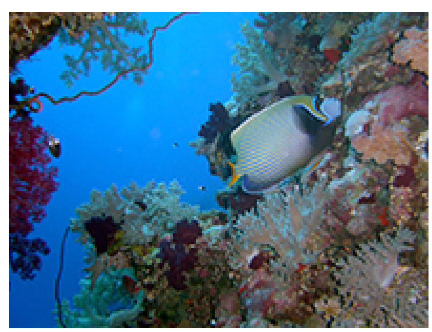

Figure. 1. Underwater image

2.2 Histogram of Colored Image

Histogram of colored image is created for each RGB channel (red, green, and blue). A histogram is a graph that displays the color distribution of a scene according to the number of each color [3]. The histogram graph arranges the pixels into 256 levels of brightness in the range of 0 (dark) to 255 (white) and stacks them according to their respective brightness, meaning there are 254 gray levels between the ranges 0 - 255.

2.3 Histogram Equalization

One of the image enhancement processes in this research is Histogram Equalization. Important information about the content of digital images can be known by creating an image histogram. An image histogram is a graph that illustrates the spread of pixel intensity values from an image or a specific part of an image. The purpose of histogram equalization is to change the image so that the output image has a flatter histogram. Histogram equalization can be calculated using the following equations:

$$S_k = \frac{(n_G - 1)}{n} \sum_{j=0}^{k} n_{r_j}$$

With:

n_G : the number of grey level images = L

n : the total number of image pixels

k : $(0, 1, \ldots, n_G - 1)$

n_{r_j} : the number of pixel tha have a gray degree of $r_j = n_i$.

2.4 Markov Random Field (MRF)

The MRF method studies the relationship between each image and the corresponding color. This method uses a multi-scale representation of the corrected color and the original image built a probabilistic enhancement algorithm. The parameters of the MRF model are learned from the most possible color assignment of each pixel. This method allows the system to adjust the color recovery algorithm to real-time conditions at the time of shooting. Specifically, MRF models studied the relationship between color images and depleted images. Color correction can be modeled as sample functions of the stochastic process based on the Gibbs distribution shown in the following equations:

$$P(X = x) = \frac{1}{Z(\beta)} \exp\left(-\beta E(x)\right)$$

The color value is set for each pixel of the image input by describing the surrounding structure using a training image patch. The MRF method uses representations between corrected imagery and bluish colors to establish the probability of algorithms that can increase colors in underwater images.

3. RESULTS

3.1 Histogram Equalization of Colored Image

Important information about the content of digital images can be known by creating an image histogram. An image histogram is a graph that illustrates the spread of pixel intensity values from an image or a specific part of an image. From a histogram can be known the relative frequency of occurrence of each grayish level value in the image. Since the degree of grayness has 256 degrees (0-255), the histogram will state the number of occurrences of each value of 0-255. It starts by input an underwater image. Furthermore, a histogram will be obtained in each channel of red, green, and blue. Histogram equalization results are necessary to improve the quality of underwater images. An example of the histogram display of each color channel is shown in Figure. 2.

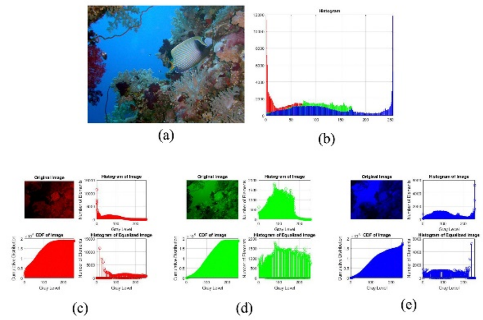

Figure. 2. Underwater image that showing the histogram of each RGB color channel: (a) the oringinal image, (b) histogram of original image, (c) the histogram of red channel, green channel (d), and blue channel (e)

The results of the colored image histogram equalization are displayed in Figure. 3.

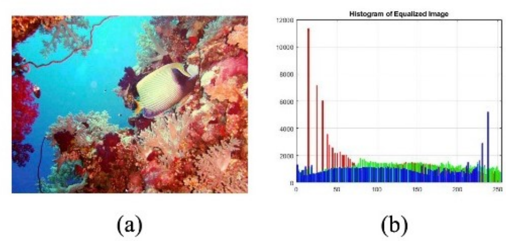

Figure. 3. The results of underwater image histogram equalization: (a) equalized image, (b) histogram of equalized image

From the images above, it can be seen that the output image of the histogram spread is more evenly distributed than the input image. With a more even distribution of histograms, the distribution of grayscale values will increase so that the output image will look brighter and the details will be more visible.

3.2 Color Correction of Underwater Images Using Markov Random Field

Measuring the difference between a depleted image (original image) and ground truth (an image with a equalized histogram) is essential for obtaining quality results, especially when there are dominant blue and green colors such as in underwater imagery. Color information can be determined, created, and visualized by different color spaces [7]. This method uses CIELab color space. This color space model has an advantage of being close to the human vision system. CIELab color space conversion is a method that used to determine compatibility functions and evaluate the performance of the Markov Random Field method. This algorithm uses pixel-based synthesis, which is that one pixel value can be estimated at a time. CIELab color space is shown in Figure. 4.

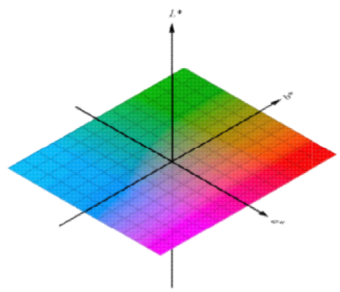

Figure. 4. CIELab color space

The conversion from RGB to CIELab can be done with the following equations.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$L^* = 116 f\left(\frac{Y}{Y_n}\right) - 16$$

$$a^* = 500\left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right]$$

$$b^* = 200\left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right]$$

With:

$$f\,q = \{\begin{matrix} q^{\frac{1}{3}} & if\ q > 0{,}008856 \\ 7{,}787q & therefor \end{matrix},$$

L* : brightness level
(a*, b*) : chromatization point.

It starts by input a depleted image as an original image and equalized image as a ground truth. Divide the depleted image and equalized image into several patches measuring 50x50 pixels. To be able to distinguish between objects in an image, patches are taken from parts of the image with varying pixel values. The image is divided into several patches so that the image patches that will be corrected to color become overlapping. Next, convert the patch into the CIELab color space. The parts of the patches will represent the overall color change of the image so that it will be an image with corrected image. Fig. 6. shows Markov Random Field color correction process by converting RGB color to CIELab.

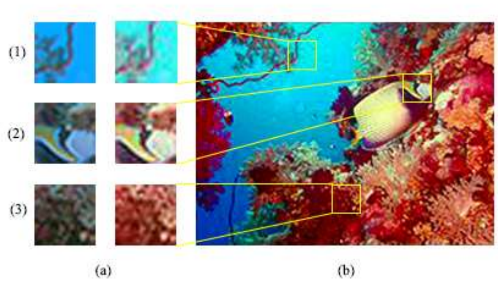

Figure. 5. (a) image patches used as ground truth, and (b) image with color correction

From Figure. 5, it can be seen that the image with color correction looks more contrast, the discontinuig on the edges of the object is maintained so as to avoid excessive image refining. Also, there are no overly contrast color changes that cause unrealistic image.

3.3 Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR)

The analysis method in this research using performance evaluation techniques by looking for MSE (Mean Square Error) and PSNR (Peak Signal-to-Noise Ratio) values. In digital images, there is a standard measurement of image quality error. The capability of an image quality improvement method is calculated using MSE and PSNR. The ability of the method of improving image quality can also be measured by visual techniques by looking at the image of the results and comparing them with the original image, however, the results of measurement of each person's visual techniques may vary. PSNR is a calculation that determines the value of a resulting image. The PSNR value is determined by the size or small value of the MSE that occurs in the image [8]. MSE and PSNR are formulated with the following equations

$$MSE = \left(\frac{1}{mn}\right)\sum_{i=1}^{m}\sum_{j=1}^{n}[u(i,j) - v(i,j)]^2$$

$$PSNR = 20Log_{10}\left(\frac{m \times n \times L^2}{\sum_{ij}[u(i,j) - v(i,j)]^2}\right)$$

With
L : maximum gray level value
m and n : rows and columns
$u(i,j)$: original image color value
$v(i,j)$: the image color value obtained from filtering result.

The first step to knowing the value of PSNR and MSE is to equate the image size between the original image, equalized image and the image with color correction. The output size of the specified image has 6 lines. Figure. 6. shows the image before and after resized

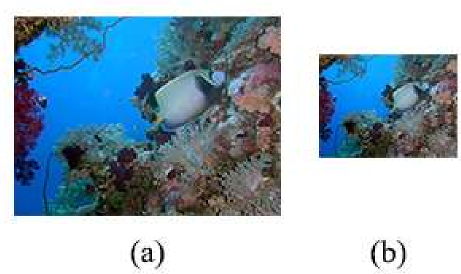

Figure. 6. (a) image before resizing, and (b) image after resizing

Calculation result of MSE and PSNR image value is shown in Figure. 7. and Table I.

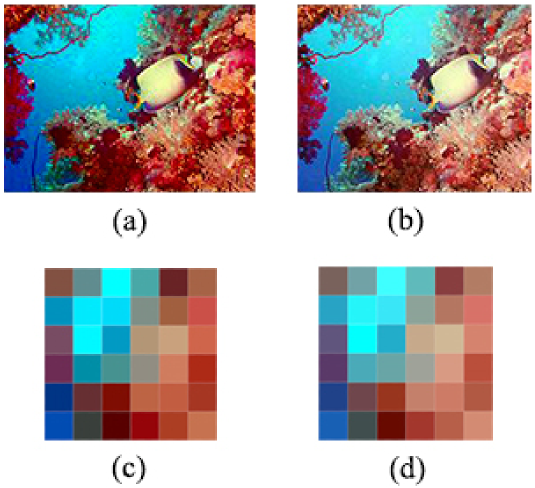

Figure. 7. (a) equalized image, (b) color corrected image, (c) and (d) are resized image of (a) and (b)

Table 1. MSE And PSNR Value

	Equalized Image	Corrected Image
MSE	143.5	51.83
PSNR	30.14	43.93

4. CONCLUSION

Low-quality images, such as underwater images, can be enhanced by histogram equalization. All pixels must be evenly distributed across the range of existing values, so that the histogram equalization can change the output image to have a flatter histogram and the information in the underwater image is more clearly visible. In color images, histogram equalization is applied to each channel and then each result is recombined. Color correction and image enhancement, especially underwater images contains many distortions that appear and are difficult to use simple methods. The MRF method uses a small number of required image patches as an example of a corrected image of a depleted image. There are several factors that affect the quality of the results, such as the adequate amount of information as input and statistical consistency of the underwater images. MSE and PSNR values between equalized image can be higher than image with color correction, and vice versa. This is affected by the lack of information on red, green, and blue color values in the underwater image so that the output image is noise.

5. REFERENCES

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