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The Analysis of Underwater Imagery System for Armor Unit Monitoring Application

Dewi Mutiara Sari[1]*, Bayu Sandi Marta[2], Muhammad Amin A[3], Haryo Dwito Armono[4]
[1,2,3]Departement of Informatics and Computer Engineering, Politeknik Elektronika Negeri Surabaya, Indonesia
[4]Ocean Engineering Department, Faculty of Marine Engineering, Institut Teknologi Sepuluh Nopember, Indonesia
[1]dewi.mutiara@pens.ac.id*; [2]bayu@pens.ac.id; [3]abdullahm181@ce.student.pens.ac.id; [4]armono@oe.its.ac.id
*Corresponding author

ABSTRACT

The placement of armor units for breakwaters in Indonesia is still done manually, which depends on divers in each placement of the armor unit. The use of divers is less effective due to limited communication between divers and excavator operators, making divers in the water take a long time. This makes the diver's job risky and expensive. This research presents a vision system to reduce the diver's role in adjusting the position of each armor unit. This vision system is built with two cameras connected to a mini-computer. This system has an image improvement process by comparing three methods. The results obtained are an average frame per second is 20.71 without applying the method, 0.45 fps for using the multi-scale retinex with color restoration method, 16.75 fps for applying the Contrast Limited Adaptive Histogram Equalization method, 16.17 fps for applying the Histogram Equalization method. The image quality evaluation uses the underwater color quality evaluation with 48 data points. The method that has experienced the most improvement in image quality is multi-scale retinex with color restoration. Forty data have improved image quality with an average of 14,131, or 83.33%. The number of images that experienced the highest image quality improvement was using the multi-scale retinex with color restoration method. Meanwhile, for image quality analysis based on Underwater Image Quality Measures, out of a total of 48 images, the method with the highest value for image quality is the contrast limited adaptive histogram equalization method. 100% of images have the highest image matrix value with an average value is 33.014.

Keywords: Armor unit; Underwater Color Image Quality Evaluation; Underwater Image Quality Measures; Image Enhancement; Image Color Restoration; Frame per Second.

Article History

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I. INTRODUCTION

Indonesia is still in the stage of accelerating the industrial revolution 4.0, where its application is still small and uneven in various sectors. One of the developments that must be pursued to accelerate the industrial revolution 4.0 is the maritime field's construction in underwater environments [1]. For example, in the construction sector, such as laying armor units (concrete rocks) for breakwaters (breakwaters) is still done using simple technology with a low level of work safety [2].

The placement of the armor units for the breakwater still uses long-arm excavators, the ends of which are replaced with clamps from the armor units. To place the armor units so that they are in the desired position, the role of the diver is needed. However, the role of divers has several limitations, namely a longer lifetime. Short time for divers due to limited oxygen and communication between excavator operators and divers because they are in different environments. This makes the work of divers in constructing laying armor units for breakwaters very high risk [3].

Armor Units for breakwaters are artificial stones made of concrete that function as the main protective layer for breakwaters [2]. Each protective stone unit must be placed individually to ensure that the placement is interrelated to have stability and strength as a group in resisting waves. Stable armor units will protect the stones beneath the armor and the smaller core layers. The breakwater will lose stability if the layer beneath the armor units is exposed—the potential to cause landslides and trigger collapse. The placement of these armor units requires that each unit be hoisted one at a time using slings or grippers, and then each unit must be placed in the water under the supervision of a diver. The diver must direct the excavator operator each time a rock is placed until the armor unit is below the water's surface. This activity endangers divers, and it is also difficult to coordinate placement between divers and excavator operators [3][4]. With the industrial revolution 4.0 that is currently developing, it should be able to replace divers with camera technology. The implementation uses computer vision because it can be safe regarding time, cost, and human safety [4]. But the underwater image issue is about the quality that is unobvious. The Green-blue dominates in the resulting image because sunlight cannot be maximally reflected underwater [5]. So, it needs image processing, such as image enhancement and image color restoration.

There are several methods used in image enhancement and color restoration. The High-Frequency Emphasis (HFE) method for image enhancement can make images look clearer and sharper. However, when using high-frequency object areas, the results tend

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to eliminate the object details [10]. In addition, an adaptive histogram equalization method can produce sharp output images, maintain image details, and avoid local areas that are too bright and have wrong contours. But this method is effective for application to images similar to CT image processing [18]. There is also the Fusion method to enhance underwater images [7]. The results show increased image and video quality, reduced noise levels, better exposure in dark areas, and increased global contrast while maintaining image details and edges. But this research has not tested real-time data yet. As for color restoration, there is the center-surround retinex method which can increase the brightness of an image [9]. But this method has a weakness in color clarity. Even though the input image has low illumination, the single-scale retinex method can work well (with high contrast without losing color vividness and edge enhancement) [12]. However, single-scale retinex cannot simultaneously use dynamic range compression and tonal rendition.

Based on the methods that have been developed and their advantages and disadvantages. This study applies histogram equalization, contrast-limited adaptive histogram equalization, and multi-scale Retinex. It uses color restoration methods for image enhancement and color restoration. This study aimed to conduct an in-depth quantitative and qualitative examination of picture enhancement and color restoration techniques. In addition, it also describes an analysis of the visualization performance of this system.

The difference between this study and the previous one [8] is that in this study, the researcher developed a variable lighting level in data testing that affects the qualitative and quantitative evaluation of image enhancement and color restoration. Whereas in previous research, the lighting level was constant. In addition, in this study, there is an analysis of visualization performance.

II. METHOD

This section will discuss the three comparison methods used in this research and the two matrix evaluations that use underwater color image quality evaluation and underwater image quality measures.

A. Histogram Equalization

Nowadays, histogram alignment and modification are used to enhance the image by increasing the contrast. However, a known method for calculating the equalization histogram has several drawbacks that reduce the efficiency of using this technique. The traditional definition of the global histogram equalization equation is often defined as Equation (1):

$$a_j = U(b_j) = \sum_{m=0}^{j} q(b_m) = cdf(b_j) \tag{1}$$

Where, the variable b_j is the brightness quantity of the *m-th* pixel of the image source; a_j is the brightness of the *j-th* pixel of the transformed image; $cdf(b_j)$ is the cumulative distribution function; and $q(b_m)$ is the density probability function of brightness.

Then there is an improved method for Histogram Equalization [6], especially for the histogram alignment that satisfies the basic requirements for the intensity of the transforming image and fulfilling the criteria of self-duality. The formulation is derived using Equations (2) to (5).

$$U(b_j) = \sum_{m=0}^{j} \Delta_m + \alpha \tag{2}$$

$$\alpha = \frac{-q(b_{min})}{2-q(b_{max})-q(b_{min})} \tag{3}$$

$$\Delta_m = \frac{q(b_{m-1})+q(b_m)}{2-q(b_{max})-q(b_{min})} \tag{4}$$

$$U(b_j) = \frac{2cdfb(_j)-q(b_j)-q(b_{min})}{2-(b_{max})-q(b_{min})} \tag{5}$$

Where, the variable $U(b_j)$ is the brightness of the transferred image. The variable α is the brightness shifts; $cdf(b_j)$ is the cumulative distribution function. The density probability function of brightness can be represented by the variable $q(b_m)$. The variable can represent the increment of *m-th* brightness Δ_m. Meanwhile, the algorithm of histogram equalization is explained as,

- Reading the input image
- Calculating the grayscale
- Calculating the histogram
- Calculating the transform function
- Updating the pixel value

The expectation is the image pixel histogram becomes more spread out. Although it won't be the same throughout, the histogram is more evenly distributed. Histogram alignment is done by changing the grayscale of a pixel with degrees. The new grayscale uses a transform function.

B. Contrast Limited Adaptive Histogram Equalization

The CLAHE algorithm can be explained as histogram equalization is the most well-known procedure Image processing in the spatial domain is based on intensity transformation [11]. The algorithm of contrast-limited adaptive histogram equalization can be explained as:

- The input image is transformed into a sub-image with the matrix size *M x N*
- Calculating the histogram for each sub-image
- Applying the clip limit value for each sub-image
- Limited contrast histogram for each sub-image processed with Histogram Equalization. Next, the pixels of the sub-image are mapped using linear interpolation

The number of sub-image pixels is distributed at each grayscale. The average number of pixels in each grayscale is Equations (6) and (7).

$$M_{ave} = \frac{M_{CR-Yp} * M_{CR-Zp}}{M_{gray}} \tag{6}$$

$$M_{ClipLimit} = M_{Clip} * M_{ave} \tag{7}$$

Where the variable M_{ave} is the average number of a pixel; M_{gray} is the grayscale number of the sub-image; $M_{CR-Yp}$is the number of pixels in the *Y* dimension of the sub-image; $M_{CR-Zp}$is the number of pixels in the *Z* dimension of the sub-image; $M_{ClipLimit}$ is the clip limit; and M_{Clip} is the maximum value of the average pixel for each sub-image grayscale.

In the original histogram, pixels will be clipped if the number of pixels is greater bigger than NCLIP. The number of pixels is evenly distributed into each gray degree defined by the total number of pixels clipped M_{TC} using Equation (8).

$$M_d = \frac{M_{TC}}{M_{gray}} \tag{8}$$

To calculate the Contrast Limited Histogram (H_{Sl}) for the sub-image, can be used Equation (9) to (11).

$$if\ H_{Sl} > M_{ClipLimit}, H_{NSl}(j) = M_{ClipLimit} \tag{9}$$

$$else\ if\ H_{Sl}(j) + M_d \geq M_{ClipLimit}, H_{NSl}(j) = M_{ClipLimit} \tag{10}$$

$$else\ H_{NSl}(j) = M_{SL}(j) + M_d \tag{11}$$

The remaining number of cropped pixels is expressed as the M_{RP}, the distribution stage pixels D are formulated in Equation (12).

$$D = \frac{M_{gray}}{M_{RP}} \tag{12}$$

Suppose the search is terminated before all pixels have been evenly dispersed. In that case, it will be recalculated using the Equation from earlier, and a fresh search will be begun until all of the pixels have been evenly distributed. As a result, a brand new histogram will be created.

C. Multi-Scale Retinex with Color Restoration

Multi-scale Retinex with color restoration (MSRCR) is the development of Multi-scale Retinex, which is capable of improving the quality of the image that is on the enlightenment of the image with maintain color constancy [13]. Color constancy or color provisions taken from the human vision system that seeks color from an object still looks the same even in different lighting conditions [14]. The Equation for the multi-scale retinex with color restoration (MSRCR) method using Equations (13) to (17).

$$CR_j(a,b) = \left\{log\ log\left[\omega I_j(a,b)\right] - log\ log\left[\textstyle\sum_{j=1}^{k} I_j(a,b)\right]\right\}\gamma \tag{13}$$

$$R_{MCR_j}(a,b) = CR_j(a,b) R_{MSR_j}(a,b) \tag{14}$$

Where, the $CR_j(a,b)$ is the color restoration; ω is the non-linear control; γ is the gain constant; k is the color channel; and R_{MSR_j} is the multi-scale retinex.

$$R_{MSR_j} = \textstyle\sum_{i=1}^{I} W_I RSR_j \tag{15}$$

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Where the variable I is the number of used scales; W_I is the associated weight of *i-th* scale; and RSR_j is the output from Single-Scale Retinex associated with the *i-th* scale; the *j* symbol represents the color channel.

$$RSR_j(a,b) = -\log\left[F(a,b) * I_j(a,b)\right] \tag{16}$$

$$F(a,b) = \frac{1}{2\pi\sigma^2} e^{-[(a^2+b^2)/\sigma^2]} \tag{17}$$

Where the variable $I_j(a,b)$ is the image distribution on *(a,b)* pixel; j is the color channel; and σ is the sigma constant.

D. Underwater Color Image Quality Evaluation

The research in the CIELab color space shows that the sharpness factor and color correlate well with subjective image quality perceptions. Based on this, underwater color image quality evaluation (UCIQE) [15], a linear combination of chroma, saturation, and contrast, was proposed to measure non-uniform color casts, opacity, and low contrast that characterizes underwater engineering and monitoring. The matrix underwater color image quality evaluation underwater image quality evaluation for *I* images in color space CIELab can be defined as,

$$Underwater\ Color\ Image\ Quality\ Evaluation = k_1\alpha + k_2 cons_{luminance} + k_3 sat_{ave} \tag{18}$$

Where the variable k_1, k_2, k_3 is the coefficient of UCIQE; α is the chroma standard deviation; $cons_{luminance}$ is the luminance contrast; and sat_{ave} is the saturation average.

E. Underwater Image Quality Measures

The research of Karen Panetta et al. explained that underwater images suffer from blurry, low contrast, and color effects gray due to absorption and scattering effects underwater. An image enhancement algorithm has been developed to enhance the visual quality of images underwater. Unfortunately, no objective measure well received can evaluate the quality of underwater images similar to human perception. The bottom image processing algorithm, dominant water, use subjective evaluation, which is time-consuming and biased, or a measure of general image quality. It fails to consider underwater image properties. His investigation uncovered a novel approach to solving the issue, and it is as follows: non-reference for underwater image quality measures (UIQM) [16]. The underwater image quality measures consist of three attribute measures for underwater images: underwater image colorfulness measure (UICM), underwater image sharpness measure (UISM) measure, and size underwater image contrast measure (UIConM). Each attribute is selected to evaluate one aspect of underwater image degradation, and each measure of the attributes presented is inspired by the human visual system characteristics (HVS). The formula for underwater image quality measures can be seen in Equation (19).

$$Underwater\ Image\ Quality\ Measure = k_1 UICM + k_2 UISM + k_3 UIConM \tag{19}$$

III. RESULT AND DISCUSSION

This section will be divided into three parts: experimental setup, image enhancement and color restoration qualitative evaluation, image enhancement and color restoration matrix evaluation, and visualization performance. The image type processed in this research is the **.jpg* file type. The resolution of the image is 640 x 480 using RGB image.

A. Experimental Setup

For the prototype used in this research is depicted in Fig. 1.

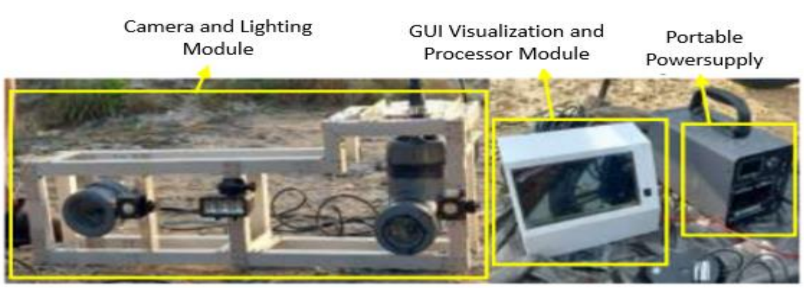

Fig. 1. Prototype Module

The module comprises two cameras, three lightings, a GUI visualization module, a processor module, and a power supply module. The brightness level that happened when the experiment was conducted was 81,67 cm. The brightness level is measured using a Secchi disc. For the design system of this research is illustrated in Fig. 2.

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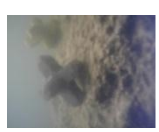
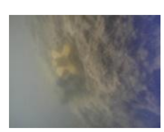
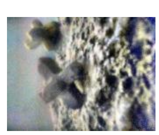
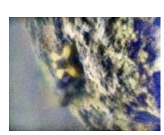
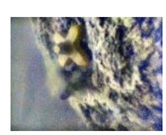
Fig 2. Pipeline Research

Based on Fig. 2 (the pipeline research), there are three comparison methods used in this research, two evaluation matrixes for the image enhancement and color Restoration method and an evaluation regarding the performance of the visualization that is conducted by calculating the frame per second.

B. Image Enhancement and Color Restoration Qualitatively Evaluation

In this research, the methods used are histogram equalization, contrast-limited adaptive histogram equalization, and multi-scale retinex with color restoration. With the same input images, there will be compared qualitatively about the result for those methods. The experiment is conducted for a depth of 50 cm, and the distance between the camera and the object (armor unit prototype) is 20 cm and 50 cm. The lighting is set in 0 Lux, 500 Lux, and 1000 Lux. The result is summarized in Table I and Table III.

TABLE I
METHOD COMPARISON WITH DEPTH 50 CM AND DISTANCE 20 CM

Method	0 Lux	500 Lux	1000 Lux
Original Image			
Histogram Equalization			
Contrast Limited Adaptive Histogram Equalization			

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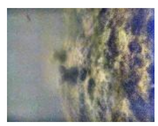
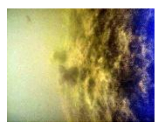
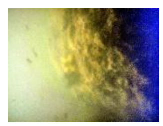
Method	0 Lux	500 Lux	1000 Lux
Multi-scale Retinex with Color Restoration			

Based on Table I, they can qualitatively compare the result using those methods. After using the methods, all the images show cleaner and more colorful. The object also shows more obvious by using the methods. This experiment is conducted for a depth of 20 cm, and the distance between the object and the camera is 50 cm.

TABLE II
METHOD COMPARISON WITH DEPTH 50 CM AND DISTANCE 50 CM

Method	0 Lux	500 Lux	1000 Lux
Original Image			
Histogram Equalization			
Contrast Limited Adaptive Histogram Equalization			
Multi-scale Retinex with Color Restoration			

The same as Table I, but in Table II, the experiment is conducted for a depth is 50 cm, and the distance between the camera and the object is 50 cm.

C. Image Enhancement and Color Restoration Matrix Evaluation

In this part, the quality of the image will be explained quantitatively (the previous part is a qualitative evaluation). This part, there will be divided into two matrix evaluations. Histogram equalization (HE), contrast limited adaptive histogram equalization (CLAHE) with clip limit (4,4);(4,7);(7,1), and (7,7). The multi-scale retinex with color restoration (MSCR) are all utilized in the processing of every image that is read in. The scenarios that are conducted for this measurement are summarized in Table III.

TABLE III
IMAGE ENHANCEMENT AND COLOR RESTORATION MATRIX EVALUATION SCENARIOS

Distance (Cm)	Depth (Cm)	Lighting Level (Lux)			
100	100				
100	50				
20	100	Level 1 : 250 Lux	Level 2 : 500 Lux	Level 3 : 750 Lux	Level 4 : 1000 Lux
20	50				
50	100				
50	50				

The analysis is measured for both camera 1 and camera 2. So total data is 48 sample images from 48 videos for each camera. The first evaluation is Underwater Color Image Quality Evaluation that is applied for camera 1. The result is summarized in Table IV.

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TABLE IV
UNDERWATER COLOR IMAGE QUALITY EVALUATION OF CAMERA 1

Level (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAHE (4,4)	CLAHE (4,7)	CLAHE (7,1)	CLAHE (7,7)	MSRCR
250	100	100	14,636	7,223	6,884	1,416	6,644	11,774
250	100	50	9,192	5,234	5,025	9,192	5,156	12,328
250	20	100	15,021	6,512	6,072	15,021	6,693	1,953
250	20	50	14,458	621	5,683	1,447	6,619	14,242
250	50	100	9,619	5,519	5,146	9,619	5,478	15,623
250	50	50	8,919	4,941	4,826	8,904	5,536	10,898
500	100	100	9,024	6,225	5,841	9,024	5,812	13,906
500	100	50	8,907	5,178	4,922	8,907	5,095	14,424
500	20	100	*14,698*	7,087	658	*14,698*	6,671	12,309
500	20	50	9,684	6,093	5,881	9,684	7,023	11,202
500	50	100	8,123	5,668	5,373	8,121	5,555	14,663
500	50	50	988	5,378	5,122	9,865	5,381	11,453
750	100	100	11,547	6,596	6,167	11,547	6,185	16,454
750	100	50	9,524	5,361	5,098	9,524	5,249	1,512
750	20	100	13,129	709	6,542	12,788	6,704	11,968
750	20	50	9,553	6,103	5,906	9,556	7,022	11,807
750	50	100	10,474	5,865	5,358	10,474	5,646	13,413
750	50	50	9,957	5,679	5,456	9,956	5,584	13,688
1000	100	100	10,026	6,402	5,909	10,208	5,996	16,732
1000	100	50	9,242	5,379	5,104	9,242	5,268	13,721
1000	20	100	*1,578*	6,849	6,462	*1,578*	685	13,107
1000	20	50	11,322	6,331	5,843	11,335	7,111	11,577
1000	50	100	1,22	5,164	4,814	12,192	519	9,604
1000	50	50	10,026	543	5,149	10,029	5,477	11,537

Meanwhile, the Underwater Color Image Quality Evaluation that is applied for camera 2 is summarized in Table V.

TABLE V
UNDERWATER COLOR IMAGE QUALITY EVALUATION OF CAMERA 2

Leve (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAH (4,4)	CLAH (4,7)	CLAH (7,1)	CLAHE (7,7)	MSRCR
250	100	100	11,068	5,566	5,221	11,068	5,365	18,293
250	100	50	10,842	5,124	4,893	10,842	5,112	12,136
250	20	100	14,746	7,763	7,378	13,678	6,972	22,024
250	20	50	13,597	6,601	6,049	13,569	7,243	16,817
250	50	100	9,979	5,974	5,698	9,979	5,762	17,731

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Leve (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAH (4,4)	CLAH (4,7)	CLAH (7,1)	CLAHE (7,7)	MSRCR
250	50	50	13,659	5,428	5,133	13,658	5,472	1,397
500	100	100	10,994	5,828	5,509	10,994	5,579	12,053
500	100	50	12,782	5,161	4,869	12,751	5,052	18,168
500	20	100	15,273	7,719	7,481	14,935	7,215	23,217
500	20	50	14,632	6,117	5,737	1,469	7,043	12,053
500	50	100	10,559	625	5,826	10,559	604	18,281
500	50	50	12,679	5,044	4,713	12,679	5,094	14,397
750	100	100	10,428	6,181	5,782	10,428	5,919	12,155
750	100	50	12,792	5,248	4,994	12,792	5,075	20,344
750	20	100	15,572	767	7,207	15,318	6,866	23,021
750	20	50	14,335	6,404	5,872	14,086	6,831	12,155
750	50	100	13,311	628	5,943	13,311	5,997	18,081
750	50	50	11,657	5,358	5,092	11,657	5,453	16,178
1000	100	100	10,061	5,785	5,483	10,061	5,674	11,534
1000	100	50	11,795	5,033	4,771	11,794	5,042	2,173
1000	20	100	14,015	6,853	6,296	1,401	6,446	25,628
1000	20	50	14,756	6,187	5,689	14,403	6,669	11,534
1000	50	100	10,635	6,369	5,947	10,636	6,077	18,227
1000	50	50	11,353	5,096	4,864	11,353	5,347	12,379

Based on Table V and Table VI, the underwater color image quality evaluation shows the calculation result using the underwater color image quality evaluation formulation. The image input for the formulation is the output of each image applied for each method. So, every method and every scenario has a different result. So, to measure which image has a good quality, it has the highest result number (after the underwater color image quality evaluation formulation is applied). The highest result is signed by a yellow color table cell in all the tables of 48 data from Table V and Table VI; 6 data have the highest result in the Histogram Equalization method (HE); 2 data have the highest result in the contrast limited adaptive histogram equalization method (CLAHE), and 40 data have the highest result in multi-scale retinex with color restoration (MSCR). Then the next evaluation is underwater image quality measures applied for camera 1. The result is summarized in Table VI.

TABLE VI
UNDERWATER IMAGE QUALITY MEASURES OF CAMERA 1

Level (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAHE (4,4)	CLAHE (4,7)	CLAHE (7,4)	CLAHE (7,7)	MSRCR
250	100	100	23,402	30,871	31,160	30,825	31,556	26,530
250	100	50	25,612	32,427	32,342	32,703	33,093	25,661
250	20	100	27,046	32,376	32,934	32,900	33,599	28,889
250	20	50	30,111	33,290	33,395	32,301	33,117	29,514
250	50	100	25,844	32,794	32,849	33,375	33,695	27,017
250	50	50	27,883	34,142	34,036	33,797	33,695	25,255
500	100	100	22,781	31,571	32,096	31,338	32,175	24,863

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Level (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAHE (4,4)	CLAHE (4,7)	CLAHE (7,4)	CLAHE (7,7)	MSRCR
500	100	50	24,401	31,628	31,741	32,375	32,716	24,951
500	20	100	27,843	32,962	33,321	33,332	33,674	28,328
500	20	50	28,848	33,229	33,120	32,189	32,704	28,160
500	50	100	23,894	32,588	32,875	32,836	33,238	23,946
500	50	50	27,670	32,783	32,673	32,940	33,102	27,352
750	100	100	23,402	32,093	32,570	31,525	32,434	26,536
750	100	50	25,027	32,313	32,396	32,294	32,977	24,807
750	20	100	25,190	30,811	31,432	30,778	31,780	26,926
750	20	50	28,982	33,725	33,720	32,269	32,876	27,769
750	50	100	25,363	32,422	32,666	32,861	33,599	28,119
750	50	50	25,321	32,377	32,499	32,597	33,011	25,734
1000	100	100	23,212	32,261	32,559	31,501	32,390	25,512
1000	100	50	24,212	32,512	32,505	32,390	32,878	24,177
1000	20	100	27,715	33,065	33,322	33,134	33,427	27,761
1000	20	50	30,075	33,694	33,593	32,588	33,028	29,672
1000	50	100	27,933	32,916	33,119	34,102	34,268	27,693
1000	50	50	27,790	33,193	33,168	32,714	33,226	26,084

For underwater images, quality measures applied for 2 Camera are summarized in Table VII. The same analysis was used for the previous evaluation. The underwater image quality measures formulation was used in this part. All 48 data from Table VI and Table VII have the highest result in the contrast limited adaptive histogram equalization method (CLAHE).

TABLE VII
UNDERWATER IMAGE QUALITY MEASURES OF CAMERA 2

Level (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAHE (4,4)	CLAHE (4,7)	CLAHE (7,4)	CLAHE (7,7)	MSRCR
250	100	100	19,839	30,821	31,061	31,595	32,474	23,667
250	100	50	24,685	31,844	31,935	3,231	32,717	25,619
250	20	100	23,219	30,241	31,111	3,028	31,267	24,728
250	20	50	28,363	33,265	33,519	31,889	32,708	27,758
250	50	100	23,358	3,243	32,834	3,254	33,109	23,212
250	50	50	26,721	32,148	32,297	3,258	33,083	27,117
500	100	100	2,151	31,366	31,973	3,162	32,315	23,249
500	100	50	25,798	3,238	32,383	33,099	33,492	26,083
500	20	100	22,559	30,828	31,699	30,922	32,183	27,458
500	20	50	30,321	33,499	33,529	32,943	3,331	30,725
500	50	100	19,235	31,317	31,816	31,128	32,529	2,183
500	50	50	27,248	31,912	32,073	32,986	33,143	27,058

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Level (Lux)	Distance (Cm)	Depth (Cm)	Methods					
			HE	CLAHE (4,4)	CLAHE (4,7)	CLAHE (7,4)	CLAHE (7,7)	MSRCR
750	100	100	22,476	32,736	3,284	31,942	32,524	22,417
750	100	50	25,542	32,019	32,288	32,844	33,286	25,782
750	20	100	23,188	31,274	32,198	31,406	32,688	28,072
750	20	50	30,488	32,826	32,833	32,542	33,105	29,612
750	50	100	21,672	32,185	3,25	32,272	32,998	22,558
750	50	50	27,583	33,008	33,179	32,707	33,346	26,641
1000	100	100	2,138	31,888	32,348	31,652	32,516	22,381
1000	100	50	25,884	32,362	32,529	32,775	33,217	26,221
1000	20	100	22,868	31,068	3,194	31,187	32,394	25,996
1000	20	50	30,845	33,439	3,351	32,797	33,581	30,318
1000	50	100	19,363	31,326	31,788	31,214	32,575	21,943
1000	50	50	26,583	32,972	32,993	33,252	33,523	26,465

D. Visualization Performance

Visualization performance is measured by testing the access of these two cameras by running the program's main page and counting the number of frames captured and the time needed so that frames per second (fps) can be obtained. This test is carried out with several devices, the size of the page layout main, and different locations. The device used is a laptop, raspberry pi 3 B 1GB, and Raspberry Pi 4 B 4GB [17], for layout size. This main page is divided into two, namely 1280x640 pixels and 800x480 pixels. This is because it follows the size of the camera's maximum resolution (640x480 pixels per camera) and adjusts the screen touchscreen's resolution so that the video capture size must be resized to 400x300 pixels per camera. This test is also carried out in conditions. The complete scenarios are summarized in Table VIII.

TABLE VIII
THE SCENARIO OF VISUALIZATION PERFORMANCE ANALYSIS

Scenario Index	Device	Main Page Layout Size	Location
A	Raspberry 3B 1 GB	1280 x 640	Indoor
B	Raspberry 4B 4 GB	1280 x 640	Indoor
C	Laptop	1280 x 640	Indoor
D	Raspberry 4B 4 GB	800 x 480	Indoor
E	Laptop	800 x 480	Indoor
F	Raspberry 4B 4 GB	800 x 480	Outdoor (seaside)

The result of visualization performance (by analyzing the fps value) is summarized in Table IX. Based on Table X, it can be seen that the average frame per second for the original image is 20.71 fps. Then the average frame per second of the histogram equalization method is 16.17 fps. The average frame per second when implementing contrast-limited adaptive histogram equalization is 16.75 fps. And the average frame per second is 0.45 fps when implementing multi-scale retinex with Color Restoration. So based on the result of the frame per second value, multi-scale retinex with color restoration has the lowest value. The lower the frame value per second, the worse the visualization performance. The low frame value per second affects the quality of data transmission, which does not provide real-time data transmission.

TABLE IX
RESULT OF VISUALIZATION PERFORMANCE

Scenario Index	Minute	FPS Average Value (fps)			
		Original	Histogram Equalization	Contrast Limited Adaptive Histogram Equalization	Multi-scale Retinex with Color Restoration
A	10	12,74	8,12	6,46	0.07
	30	13,00	9,80	7,59	0,06
	60	13,01	10,1	7,88	0,06
B	10	20,77	16,26	14,27	0,15
	30	21,17	17,87	13,13	0,14
	60	22,50	18,29	12,94	0,13
C	10	25,99	25,90	24,24	0,75
	30	27,14	25,95	24,89	0,72

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Scenario Index	Minute	FPS Average Value (fps)			
		Original	Histogram Equalization	Contrast Limited Adaptive Histogram Equalization	Multi-scale Retinex with Color Restoration
	60	25,95	25,60	25,17	0,73
D	6	20,77	19,35	18,10	0,26
	11	21,40	19,34	18,37	0.26
E	6	23,68	24,40	22,10	1,45
	11	24,41	23,82	23,06	1,45
F	6	20,30	18,43	17,06	0,26
	11	17,90	17,99	15,98	0,26

IV. CONCLUSION

This research purpose is to make a vision system of armor unit positioning. There are some analyses to evaluate the system. These are qualitative evaluation for image quality, image enhancement and color restoration matrix evaluation, and visualization performance. Based on the experiment in this research, the image that applied the method (histogram equalization, contrast limited adaptive histogram equalization, and multi-scale retinex with color restoration) qualitatively has increased the output. Meanwhile, the quantitative evaluation through underwater color image quality evaluation and underwater image quality measures. The result of the underwater color image quality evaluation shows that 83,33% of data images experienced the most significant improvement by using multi-scale retinex with color restoration method.

Meanwhile, using the underwater image quality measures matrix, 100% of the method that achieves the most significant improvement is the image with contrast limited adaptive histogram equalization method. Then, the visualization performance is evaluated by measuring the frame per second (fps) using multi-scale retinex with color restoration method. The average fps is 0,45 fps using the contrast limited adaptive histogram equalization method, the average fps is 16,75 fps using the histogram equalization method, and the average fps is 16,17 fps.

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