Development of Lighting System for Imitating Multi Depth Underwater Light Condition

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Abstract

This paper describes the development of the lighting system for simulating the underwater environment at different depth. The major obstacle faced by the underwater environment system is the extreme loss of colour and contrast when submerged to any significant depth whereby the image quality produced is low. The studies can easily carry out by developing the prototype of lighting system that imitates the underwater environment. Thus, suitable lighting system with the right colour options are selected where it act as an imitator for underwater environment at different depth. By using this imitator, this prototype might be able to produce image that can be comparable with the actual environment. The water tank is the best choice as the medium for imitating and it is attached with the red curtain in order to create the environment without any unwanted lighting source or disturbances. The underwater flood light is also included and it creates the scenery of the lighting underwater environment. The brightness of the light can be adjustable by adjusting the input voltage. In order to capture and record the image of the imitated underwater, the underwater camera and recordable receiver display is used. Lastly, since the underwater environment has noise the automatic pump is applied to create the ambient noise. The result shows that the appropriate combination of colour and the brightness based on different depth it may produce the precise hue and saturation with the actual environment system.

Keywords: Lighting System; Multi-Depth; Underwater Environment condition

1. Introduction

Water is the denser substance which is 800 times denser than air. The density of air itself may influence the image quality [1]. This is because light interacts with the water molecules and suspended particles to cause loss of light, color changes, diffusion, loss of contrast and other effects [2-5]. In term of imitating the image and the environment of underwater imaging, there are few things need to be considered such as the properties of the water through light penetration and the properties of the light [6]. Water behavior tends to absorb light with longer wavelength which is red and scattered with short wavelength. As water depth is increased, the light that passes through the water may decrease. In order to obtain good image quality, the purity of water is important. Since the problem of underwater vision as the absorption of the light makes it gets dark very quickly, this may disrupt in quality imaging [7-10].

The studies of underwater surroundings are limited to explore due to lots of limitations. By imitating the underwater environment, it might overcome several limitations in underwater studies. The limitations that usually linked to this study are time consuming and high equipments cost used to explore the underwater surrounding and also the insufficient lighting systems penetrate under the sea. In addition, the specifications of underwater equipment and tools are different with imitator system [11]. For example, the camera used for actual environment must be crushproof when diving over 10 meters in order to resists the pressure of the water. Thus, by imitating the underwater environment in the water tank, there will be no wasted time and the costs needed are cheaper [12]. The other limitation of studying actual underwater environment is the safety to the diver and equipments. Engaging with the nature, there are no fully guarantees that the safety is not compromise. The natural disaster is unexpected when it may happen, for instance, tsunami and wild animal attack [13 -16].

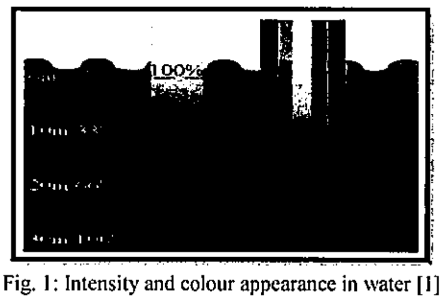

Fig. 1: Intensity and colour appearance in water [1]

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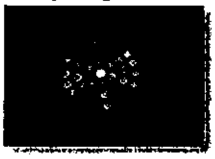
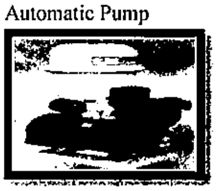
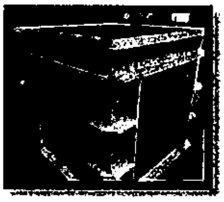
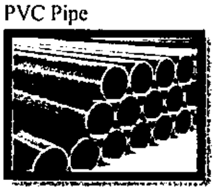
The actual intensity of underwater environment is unpredictable. To imitate the actual environment, the imitator lighting system must be setup appropriately to get desire result. By developing this kind of system, exploring the under the sea studies are easier than exploring the actual underwater environment. Therefore, imitation of the underwater environment is developed and created in order to help people to explore and study the environment of under the sea in the easiest and smartest way.

2. Hardware Design

Table 1 below listed all the materials and components that have been used for this imitator project with a brief description on the selected equipments.

Table 1: Components/Materials used in this project

Component	Description	Component	Description
Multiple Light Color 	Power up with 12V DC supply. The light can produce varies of colour like red, yellow, green and blue by changing the light casing. Led emitter power can provide until up to 10W. The characteristic of this light is waterproof and dustproof. Lifespan time can be more than 60000 hours. This project will use 4 quantities of flood light to produce 4 different colours at the same time.	AC/DC Adaptor 	AC/DC adaptor use to convert AC supply to be used for Underwater Flood Light which is us DC supply for input voltage. Input voltage for this adaptor is 220V AC with maximum load of 1000mA. The output voltage can be adjusted to 3.0/4.5/6.0/7.5/9.0/12v. Output plug have varies 6 way universal connector.
Automatic Pump 	Kikawa automatic power pump will be used to produce noise in water tank. This pump can produce 1/2HP with only 11kg of weight. Dimension of suction and delivery pipe is 25mm.	Red Curtain Studio 	Specification: →Pattern: solid; →Length x Width: 2 m x 3 m; →Dominant color: red, →Fabric: velvet This type of curtain will be used to cover-up the water tank area. Greater the width of curtain will produce approximately to zero lux.
Water Tank 	Water tank that be used will imitate the underwater environment. The maximum depth of this tank up to 2m depth. The tank will include the glass for viewing purposes.	PVC Pipe 	PVC pipe that will be used to connect to automatic pump will be 25mm of diameter. The PVC pipe will be as connection for input and output of automatic pump.
Waterproof smart phone camera 	The Sony Z1 smart phone camera can take picture up to 20.7 Mega Pixels (5248 x 3936). It also included with auto focus and auto mode feature to capture image. Plus, this device also included with LED flash. The Sony camera was certified as dust proof and water resistant over 1 meter and 30 minutes.	Lux meter 	The lux meter can display the update reading 2times per second. It can operate in such conditions as -20 °C ~ 60 °C. The measurement range of the lux meter capable of is between 0 Lux ~ 100K Lux with the accuracy of ±3% rdg ± 0.5%f (<10,000Lux), ±4% rdg ± 10dgts.(>10,000Lux). The size of the lux meter is Size 172* 55*38mm (L*W*H) with the weight of 162g. the lux meter use silicon sensor as the light detector.

3. Results

These studies require two types of tank in order to imitate the environment of the water. The environment of the underwater will be examined into two different conditions. First condition, the imitator will identify the light behaviour in the water with different depth. This imitation will be held in the tank called 'Imitator tank'. In this imitator tank, the repeatability method is used in order to get the average lux to determine the brightness of the light for different depth. By using the lighting brightness, the behaviour of the colour can be observed and recorded in RGB and HSV of the image captured. The outcomes are measured on colour conditions that are source of attenuation effects. For second condition, the tank is called 'Ripple tank' where it is use to identify the colour behaviour in two different situations which is bright light situations and dim light situations with ripple included. The ripple supplied is act as the noise in underwater where it is used for measuring the intensity of light. By using this method, the image with these two different light conditions will be captured and recorded in RGB and HSV of the colour for each situation. The results will be interpreted using visual and explanation of project finding.

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3.1 Brightness rate

There are six conditions of voltage supply for the lighting system that are used for the imitation process. For each six different voltage used, it required five repeatability test to ensure the accuracy of the data. The different voltage supply used to represent the different depth of underwater. The voltages used for this imitation process are 3v, 4.5v, 6v, 7.5v, 9v and 12v. After completed each test, the average will be calculated in order to get the suitable rate of the light for each depth. The average of the result are recorded in a Table 2 below:

Table 2: Repeatability test of brightness rate

Voltage (v)	Test1 (lx)	Test2 (lx)	Test3 (lx)	Test4 (lx)	Test5 (lx)	Average	Rounded (≈)	Lux (lx)
3	8	10	9	10	11	9.6	10	10
4.5	16	17	15	17	14	15.8	16	16
6	25	23	24	27	25	24.8	25	25
7.5	41	41	42	45	40	41.8	42	42
9	62	61	63	60	60	61.2	61	61
12	87	85	85	86	86	85.8	86	86

The relationship between voltage and lux rate are shown in Table 2. All data are repeated 5 times in order to acquire the average of the brightness rate of the lighting system. Then, the data will be rounded to the nearest decimal places in order to ease the research process. The linear relationship between lux and voltage are depicted as the lux will keep increasing when the voltage used is increased.

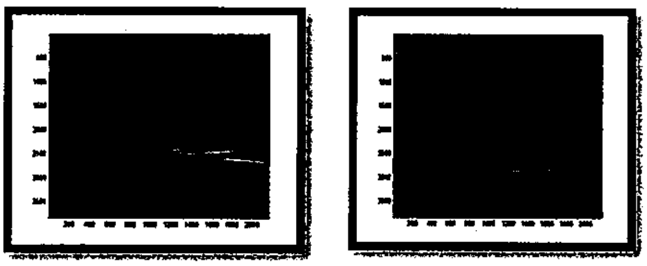
3.2 Imitation condition

From the previous lux test, the lux will keep increasing if the voltage use for the lighting system is increased. The purpose of using different voltage for the lighting system is to create the scenery with different depth of underwater condition. For each voltage used, the brightness of the light will imitate certain depth measurement of the underwater. Fig. 2 and Fig. 3 below will show the result of the imitation image in the imitator tank of different voltage.

Table 3 : Imitation image detail

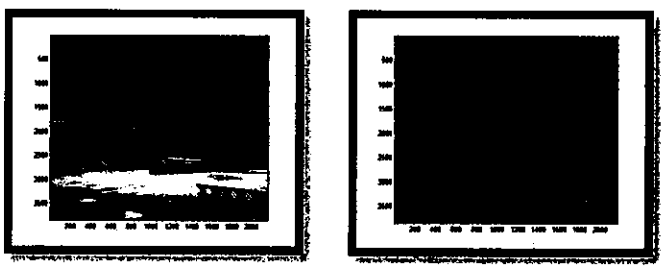
Categories	Details
Format	'jpg'
Width	2160
Height	3840
Bit Depth	24
Color Type	'true color'

Table 3 indicates the image details for each voltage supply. All images should be captured by using the same camera and with the same depth in order to get an accurate change for the voltage value given. Then, the images that are captured will be processed by using Matlab software in order to extract the data for every pixel of the images. When the voltage of 3V is supplied for the lighting system to the imitator tank. Fig. 2(a) below exhibit the result of 3V lighting system. Then, the image will be processed by using Matlab processing image to convert original image into HSV image as seen in Fig. 2(b). The 12V is used to produce the imitation image of underwater as Fig. 3(a) below. Then, the processes HSV image shown in Fig. 3(b).



(a) (b)

Fig. 2: (a) Image at 3 volt; (b) HSV image at 3 volt



(a) (b)

Fig. 3: (a) Image at 12 volt; (b) HSV image at 12 volt

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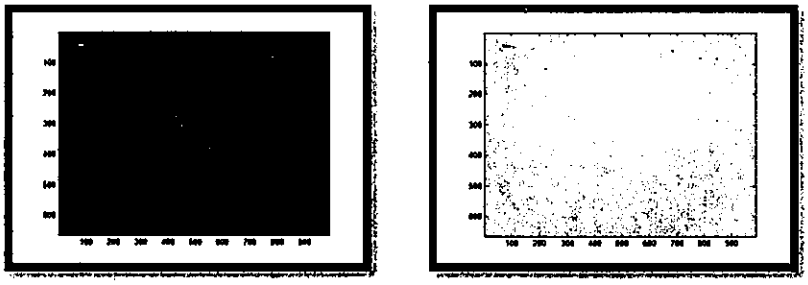
Table 4: HSV result for imitation light behavior

	Imitator tank		
Voltage (V)	H	S	V
3	0.2597	0.5791	0.2585
4.5	0.2623	0.4436	0.3728
6	0.2708	0.4414	0.4284
7.5	0.3451	0.3950	0.4664
9	0.3880	0.2950	0.4877
12	0.3888	0.2058	0.5193

Table 4 above indicates the result for HSV (hue, saturation, value) values with different voltage supplied. It can be seen that, when the light voltage supplied is increasing, the hue illustrates increasing trends. Meanwhile, the saturation value trend is decreasing. It shows that, when the 3V light is used, the saturation value became the most highest value among others at 0.5791. Then, it followed by 4.5V, which is amost similar with 6V light. Lastly, the rest three is 7.5V is almost about 0.4, 12V which is 0.3 and lastly 9V which is slightly abobe 0.2. Finally, the result that is describing value (V) is shows significant increase when the light voltage is increase. As can be seen, when the light voltage of 3V is used, the value illustrates is the lowest compare to other when the light voltage is increse. Overall, it can be said that, the highest the voltage of the light, the highest the HSV rate it may produced.

3.3 Actual image specification

The actual image was captured with the depth between 5 to 6 meters under the sea. The actual images will be compared with the system image with the same depth between 5 to 6 meters under water. In order to acquire accurate result, the actual image resolution must be the same as the system image for make it comparable. The comparable method use for this test is by using comparing the HSV rate only. Fig. 4 below represents the actual and HSV image between 5 to 6 meters depth.



(a) (b)

Fig. 4: (a) Actual image [16]; (b) HSV of actual

Table 5: Actual image condition

	Hue	Saturation	Value
Actual image	0.5678	0.9835	0.4957

It is illustrates that the saturation have the most high rate which is almost 1 compare to the hue and value rate. Meanwhile, the value rate have the lowest rate which is about half of the saturation rate. Lastly, it can be seen that the hue rate is almost the same as the value rate which is slightly below than 0.6.

3.4 Ripple tank result

The aim of this study is to imitate the environment of underwater and to analyze the light behaviour with the existence of noise. In order to do the analysis, water tank called Ripple tank is used. The tank is included with ripple which acts as noise in the water tank. The voltage supply to the ripple tank is same for all noise condition which is by using room lighting. The table below indicates the finding of lighting conditions with different rate of ripple included.

Table 6: Ripple tank repeatability test

Condition	Test1 (lx)	Test2 (lx)	Test3 (lx)	Test4 (lx)	Test5 (lx)	Average (lx)	Rounded (≈)
Normal Condition	161	162	162	160	163	161.6	162
Small noise	155	158	157	158	156	156.7	157
Higher Noise	149	147	148	150	151	149	149

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The relationship between noise condition and lux rate for bright light condition are shown in Table 6. All the data will be recorded 5 times in order to acquire the average of the brightness rate of the ripple tank system. Then, all the data will be rounded to the nearest decimal places in order to ease the research process. Fig. 5 shows the images at different lux rate or brightness rate with difference noise conditions. Images will become unclear affecting by noise inside the ripple tank. The first situation, the experiment will be held without any noise. Then followed by small noise and lastly with higher noise. For the normal condition, the brightness rate is as highest as 162 lx. Then, for small noise, the brightness rate is 154 lx. Meanwhile, for the higher noise, rate is 149 lx. As conclusion, it can be seen that, the higher the noise includes, the smaller the brightness rate will be acquire from the experiment.

(a) (b) (c)

Fig. 5: (a) Normal condition with lux 162, (b) Small noise with lux 157, (c) Higher noise with lux 149

4. Conclusion

As a conclusion, the lighting system for imitating underwater environment is successfully designed. From the captured images, the light and colour behaviour of object in an underwater environment can be differentiated easily. This lighting system or simulator can greatly contribute to the studies and analysis of underwater images. This project is also important to the underwater technology studies such as unmanned underwater vehicles like an ROV (remotely underwater vehicles), AUV (autonomous underwater vehicles, underwater gliders and others.

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