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SIMULATING UNDERWATER DEPTH ENVIRONMENT CONDITION USING LIGHTING SYSTEM DESIGN

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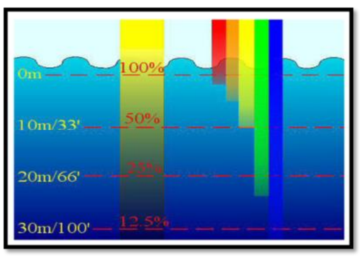
Graphical abstract



Abstract

The major obstacle faced by the underwater environment system is the extreme loss of color and contrast when submerged to any significant depth whereby the image quality produced is low. The studies can be easily done by developing the prototype that may imitate the underwater environment. In order to develop the prototype, suitable lighting system are used where it act as an imitator for underwater environment with different depth. Next the color option that use for the imitator prototype should be suitable for underwater lighting system. By using both suitable lighting system and color option for the system, 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's attached with the red curtain in order to create the environment without any unwanted lighting source. The underwater flood light is use for the lighting system and 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 color 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

Abstrak

Halangan utama yang dihadapi sistem bawah air ialah kehilangan warna dan kontras apabila ditenggelamkan pada kedalaman yang jauh dimana kualiti imej yang dihasilkan adalah rendah. Kajian boleh dilakukan dengan mudah dengan membangunkan prototaip sistem pencahayaan yang sesuaiyang boleh digunakan sebagai replica persekitaran bawah air dengan kedalaman berbeza. Kemudia, warna yang digunakan untuk prototaip replica seharusnya sesuai untuk sistem pencahayaan bawah air. Dengan menggunakan sistem pencahayaan yang sesuai dan pilihan warna, prototaip boleh menghasilkan imej yang boleh dibandingkan dengan persekitaran sebenar. Tangki air ialah pilihan terbaik dan ianya disambung dengan kain merah untuk menghasilkan persekitaran tanpa pencahayaan yang tidak dikehendaki. Lampu banjir bawah air digunakan dan menghasilkan pemandangan pencahayaan persekitaran bawah air. Kecerahan lampu boleh diubah dengan melaraskan voltan masukan. Untuk merekod imej persekitaran bawah air yang dicipta, kamera bawah air dan pemapar penerima boleh rekod digunakan. Disebabkan persekitaran bawah air mempunyai hingar, pam automatic digunakan untuk menghasilkan hingar ambien. Keputusan menunjukkan campuran warna yang bersesuaian dan kecerahan berdasarkan kedalaman berbeza akan menghasilkan 'hue' tepat dan ketepuan dalam sistem persekitaran yang sebenar.

Kata kunci: Sistem pencahayaan, kedalaman berbeza, keadaan persekitaran bawah air

1.0 INTRODUCTION

Water is the denser substance which is greater than 800 times 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 [2-3] as shown in Figure 1. In terms 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 [4-7]. 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 [8-10].

Environment underwater studies are limited to explore. There are a lot of limitations. By imitating the underwater environment, this may be one of the ways to overcome the limitations for underwater study. The limitations that usually related to the underwater studies are costly in general, the equipment used to explore the underwater, and the sufficient lighting system since under the sea is not the same as on the ground. The equipment and tools used for the actual underwater environment is a bit expensive and the specification is different than the the imitated 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 weight of the water. By imitating the underwater environment in the water tank, there is no time will be wasted and the money/cost needed are cheaper. The other limitation of studying actual underwater environment is safety [12 -13]. Engaging with the nature, there are no guarantees that the safety is not compromised. The natural disaster is unexpected and it can happen anytime, for instance, tsunami and wild animal attack.

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 under environment is developed and created in order to help people to explore and study the environment of under the sea easier and smartest way.

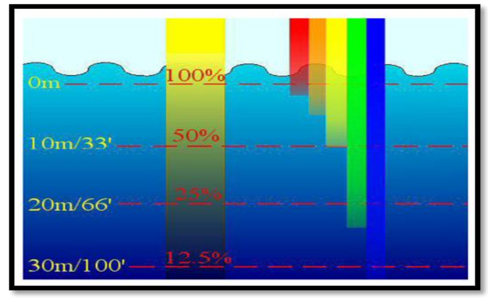


Figure 1 Intensity and color appearance in water [1]

First, the problem statement is how to produce the dark channel of the underwater environment (sea water). Normally, the dark channel prioritization is used to get clearer images of underwater by removing haze [13]. The low intensities in the dark channel are mainly due to three factors which are from shadows, colorful object and dark surface [14]. Next, for the second problem statement was the lighting system behavior. For the actual environment, sunlight is the source of light for marine and terrestrial. The light suffers when it passes through the water. The water may produce a scattering problem, where the photons of the light bounced into different traveling path from the original path [15-16]. This phenomenon happens when the incident light is entering into the water it interacts with water molecules and particles. Reflection is the change in direction of a wave front at an interface between two different media so that the wave front returns into the medium from which it originated. The reflected light is happen when the surface of the water is tranquil. Light has also suffered in term of maintaining the same amount of light when it goes deeper. The water molecule will absorb the molecule of light as it passes deeper into the water, the brightness may decrease [17-19]. Figure 2 shows the water surface effect of light.

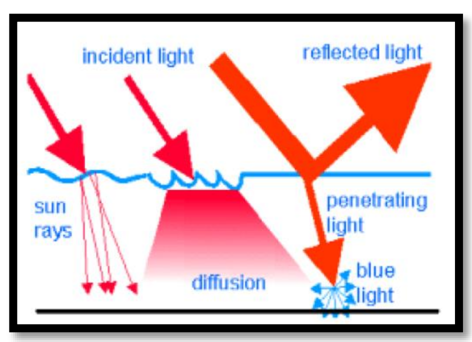


Figure 2 Water surface effect [1]

2.0 HARDWARE DESIGN

Seems that the major task of this project is analysis and research, therefore, this project might not involve with too many electrical or electronic components. Table below listed all the material or components that been used for this project, together with a brief description of each equipment. These studies require two types of tank in order to imitate the environment of the water. The environment of the underwater will be examined in two different sceneries. First, the environment imitated will identify the light behavior 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 the lighting brightness, the behavior of the color can be observed and recorded in RGB and HSV of the image captured. The outcome is measured on color condition that's the cause of attenuation effect. Besides that, it is continuing with the results of the lighting rate take that using the Lux meter. Meanwhile, for second scenery, the tank is called 'Ripple tank' where it is use to identify the color behavior 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 uses 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 color for each situation. The results will be interpreted using visual and explanation of project finding.

2.1 Brightness Rate

There are six conditions of voltage supply for the lighting system that will be used for the imitation process. For each six different voltage used, it requires five test of repeatability to ensure the accuracy of the data. The different voltage supply is 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. Then, after completed each test, the average will be counted in order to get the suitable rate of the light for each depth. The average of the result will be recorded as Table 1. Based on the Table 1, it shows the relationship between voltage and lux rate. All the data will be recorded 5 times in order to acquire the average of the brightness rate of the lighting system. Then, all the data will be rounded to the nearest decimal places in order to ease the research process.

Table 1 Brightness rate

Voltage (v)	Lux (lx)
3	10
4.5	16
6	25
7.5	42
9	61
12	86

The Table 1 above shows the result of the brightness rate for lux that will be used by each voltage supply for imitating the different depth of the tank. It can be seen that the lux will keep increase when the voltage used is increased.

2.2 Imitation Condition

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

2.3 Imitation Attenuation Effect

In order to identify the attenuation effect in the imitator tank, the image will be captured first without any colourful object. This is because the colourful object may influence the image and the result may not be an accurate result. Then, the voltage of 6v will be use for the purpose to see the appearance of the attenuation effect in the imitator tank. Images that is captured will be divided into four parts which are part 1, part 2, part 3, and part 4. Every separated part will determine the level of color loss. The part 1 is the part where is the top of the image, meanwhile, part 4 will be the bottom part of the image. The Figure 3 is illustrates the image for the 6 volt supply without any existence of colorful object.

Figure 3 Imitation image for 6 volt without any colourful object

Figure 4 Cropping image

Figure 3 above exhibits the image that is captured in the imitator tank by using of 6 voltage of lighting system. Meanwhile, Figure 4 illustrates the separated image to 4 parts. Every RGB value is recorded as in Table 2.

Table 2 RGB value for wavelength of the light

	Red	Green	Blue
Part 1	9.3267	36.9301	59.6368
Part 2	8.4512	34.2872	54.7593
Part 3	7.1607	31.6554	44.9187
Part 4	6.4360	28.6123	36.4347

Table 3 shows the color loss rate in the imitator tank for 6volt without the existence of colorful object. Base on the findings above, part 1 contains the highest rate for the RGB value. Meanwhile, part 4 contains the lowest rate of RGB value. Furthermore, from the table, it clearly shown that, the lowest the ranking of the separated part in the image, the lowest the RGB value produced.

Table 3 Imitation image detail

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

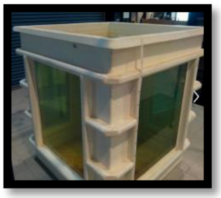
Table 3 indicates the image details for each voltage supply. All images should be captured by using the same camera and with the same depth in order to get an accurate change for the voltage value given. Then, the images that are captured will be processed by using MATLAB software in order to extract the data for every pixel of the images. When the voltage of 6v is supplied for the lighting system to the imitator tank. The figure 5(a) exhibit the result of 3v lighting system. Then, the image will be process by using Matlab processing image to convert original image into HSV image like Figure 5(b). The 12v is used to produce the imitation image of underwater as shown in Figure 6(a). Then, the image will be process by using Matlab processing image to convert original image into HSV image like Figure 6(b).

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 4. Table 5 below listed all the materials and components that have been used for this imitator project with a brief description on the selected equipment.

Table 4 Repeatability test of brightness rate

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

Table 5 Material used in this project

Components / Materials	Description
Multiple Light Color 	Power up with 12V DC supply. The light can produce varies of color 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 colors 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.
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.
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.
Red Curtain Studio 	Specification: • Pattern: solid • Length x Width: 2 meter x 3 meter • 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.
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.

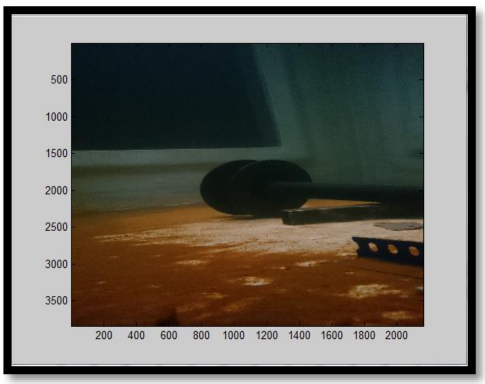


Figure 5(a) Image at 3 volt

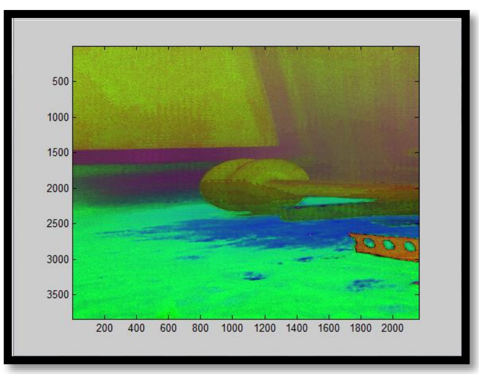


Figure 5(b) HSV at 3 volt

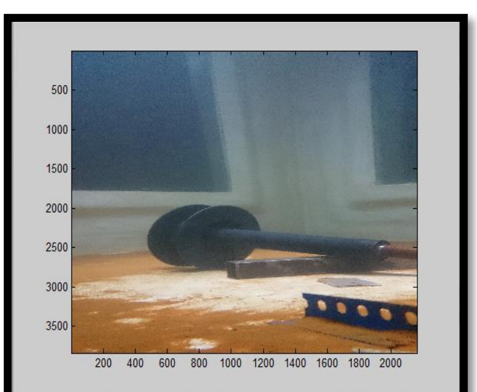


Figure 6(a) Image at 12 volt

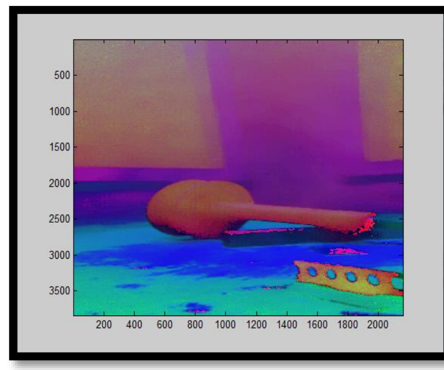


Figure 6(b) HSV at 12 volt

Table 6 HSV result for imitation light behavior

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

Based on the Table 6, it indicate the result for HSV (hue, saturation, value) value with different voltage supplied. From the graph, it can be seen that, when the light voltage supplied is keep increasing, the hue illustrates fluctuate trends. When the 3v of light is used, the hue resulting higher than when using the light with 4.5v and 6v. However, when the light of 7.5v is used, the hue value start to climb from slightly below 0.3 to 0.34. Then, the hue value of 9v and 12v is at the same level which is slightly below 0.4. Meanwhile, the saturation value trend is decreasing. The bar graph shows that, when the 3v light is used, the saturation value became the highest value among others. Then, it followed by 4.5v, which is almost 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 below 0.3.Finally, the bar graph that is describing value is resulting 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 increase. Overall, it can be said that, the highest the voltage of the light, the highest the the value it may produce.

2.4 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.

Table 7 Actual picture detail

Format	'jpg'
Width	994
Height	664
Bit Depth	24
Color Type	'true color'

Table 7 indicates the image details for actual image with depth between 5 to 6 meters under the sea. The Figure 7(a) and(b) represents the actual and HSV image between 5 to 6 meters depth.

Figure 7(a) Actual image between 5 to 6 meters depth [16]

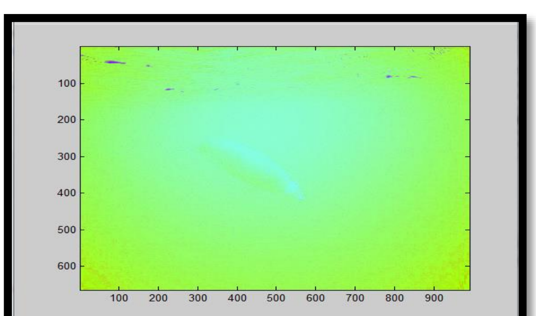


Figure 7(b) HSV of actual image between 5 to 6 meters depth

Table 8 Actual image condition

	Hue	Saturation	Value
Actual image	0.5678	0.9835	0.4957

Table 8 illustrates that the saturation have the highest 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.

3.0 RESULT AND DISCUSSION

The aim of this study is to imitate the environment of underwater and to analyze the light behavior 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.

Based on the Table 9, it shows the relationship between noise condition and lux rate for bright light condition. 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.

Figure 8(a) Image at normal condition

Figure 8(b) Image at small noise

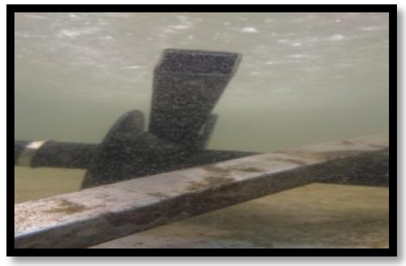


Figure 8(c) Image at higher noise

Table 9 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

Figure 8 shows the image at difference condition of noise. Images will become unclear effecting by including noise inside the ripple tank.

Table 10 Ripple tank condition

Noise	Lux (lx)
Normal condition	162
Small amount of noise	157
Higher amount of noise	149

Table 10 has indicates the brightness rate in different situation. The first situation, the experiment will be held without any noise. Then it is followed by small noise and 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 shown in Figure 9. As conclusion, it can be seen that, the higher the noise includes, the smaller the brightness rate will be acquire from the experiment. From the analysis that had been done, by producing suitable intensity for the imitator tank, the suitable depth of the underwater is properly developed. The red, green and blue rate (RGB) must exist and sufficient in the lighting system in order to support the hue, saturation and value (HSV) in the produced image. By producing the suitable imitation, the system output and the actual image can be compared verily. Noise plays the main role in determining the level of brightness in the water. The light condition will decrease as the ripple rate goes high. The existence of the ripple has influence the lux rate of the light. This is because, the ripple is act as noise in the underwater environment which can cause the scenery become blurry and unclear. Therefore, when the amount of ripple (noise) is supply, the lux rate will be disturb and the molecule of the water will scatter around and unstable.

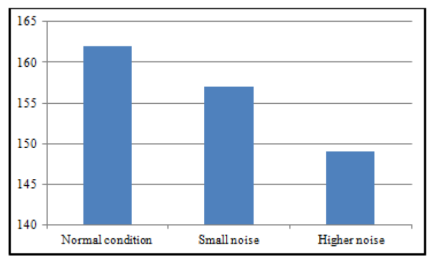


Figure 9 Light behavior

4.0 CONCLUSION

This is the last part of the report whereby it will conclude the overall performance of the project, which might comprise the overall overview of this chapter. The objective of this project is to design the lighting system for imitated underwater environment. There is still the limitation regarding to capture underwater images due to some limitation that appears. This project can be contributed for the study of underwater technology such as unmanned underwater vehicles like an ROV (remotely underwater vehicles), AUV (autonomous underwater vehicles, underwater gliders and others. From the images capture, we can differentiate the color of object in an underwater environment. This project may contribute in term creating simulator of underwater environment for study proposes and images analyses of underwater.

For this project, it's recommended to do the analysis of this project with the different type of water, such as the sea, river and others to see the differentiation of the vision through these different water densities. Besides that, it is recommended to do the more investigation about the color that cannot be seen clearly from this project. It is also recommended of using complete color features on one light system for the project in overcoming the color loss problem. Furthermore, the usages of several noise like wave and tides also can imitate the actual light behavior under the sea.

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References

[1] Karthiga R. and Ashokraj. M. 2011. Illuminance Estimation in Underwater using Color Constancy. *CARE Journal of Applied Research*. 25-29.

[2] Garcia, R. Nicosevici, T. and Cufí. X. 2002. On the Way to Solve Lighting Problems in Underwater Imaging. *Proceedings of Computer Vision and Robotic Group*. 1018-1024.

[3] Yamashita, A. Fujii, M. and Kaneko, T. 2007. Color Registration of Underwater Images for Underwater Sensing With Consideration of Light Attenuation. *Presented in Robotic and Automation*. Roma, Italy.

[4] Barngrover, C. 2010. Computer Vision Techniques for Underwater Navigation. *M.S. thesis*. University of California, San Diego.

[5] Shahrieel, M. Nadhirah, A. Farriz, M. 2009. Vision System for Autonomous Underwater Vehicle using Wireless Camera for Monitoring and Surveillances Application. *Defence and Security Technology Conference*. 1-5.

[6] Syed Mohamad Shazali bin Syed Abdul Hamid, M. Shahrieel M. Aras, Fara Ashikin binti Ali, Anuar bin Mohamed Kassim, Fadilah binti Abdul Azis. 2011. Development of Image Recognition Algorithm for Underwater Vehicle Applications. *International Seminar on the Application of Science & Mathematics*. 1-7.

[7] Syed Mohamad Shazali Bin Syed Abdul Hamid, Mohd Shahrieel Mohd Aras, Fadilah Binti Abdul Azis. 2012. Development of Image Recognition Algorithm for Deep Submergence Vehicle Applications. *4th International Conference on Underwater System Technology: Theory and Applications 2012 (USYS'12)*. 153-157.

[8] Naval Sea Systems Command Department: Ambient Noise in the Sea. 1984. *Undersea Warfare Technology Office of the NAVY*. Washington dc.

[9] Tkalich P. and Chan, E. S. 1998. On Mechanism of Wind-Wave. *Proceedings of OCEANS '98 Conference*. 3: 1378-1381.

[10] Jang, T. K. Kim, E. J. Kim, D. K. Han, Y. S. Seo, Y. S. Cho, H. S. and Lee, B. S. 2010. Design of Intelligent Water Vision System. *Proceedings of the 5th International Conference on Ubiquitous Information Technologies and Applications*. 1-3.

[11] Tiffen, I. Camera filters. Tiffen, Color-Grad, Softnet, Soft/FX, Decamired (DM), FL-D, FL-B, 812, Diffusion/FX, Pro-Mist and LL-D are registered trademarks of The Tiffen Company, LLC Hauppauge, NY 11788. [Acessed on 19 November 2013].

[12] Tian, B. Zhang, F. and Tan, X. 2013. Design and Development of an LED-based Optical Communication System for Autonomous Underwater Robots. *Conference on Advanced Intelligent Mechatronics (AIM)*. IEEE/ASME International. 1558-1563.

[13] Wu, H. Narendran, N. Gu, Y. and Bierman, A. 2007. Improving the Performance of Mixed-color White LED Systems by Using Scattered Photon Extraction Technique. *Proceedings of the 7th International on Solid State Lighting*.

[14] Fraser, A. Walker, R. and Jurgens, F. 1980. Spatial and Temporal Correlation of Underwater Sunlight Fluctuations in the Sea. *IEEE Journal on Oceanic Engineering*. 5: 195-198.

[15] Robert N. Rossier, What is Visibility. Illuminating Facts about an Unclear Situation. 2012. [Acessed on 24 December 2013].

[16] Murray, J. W. 2004. *Properties of Water and Seawater*. University Washington. 1-32.

[17] Lynne Talley, George Pickard, William Emery and James Swift. 2011. Physical Properties of Seawater. *Proceeding of the 6th Descriptive Physical Oceanography*. 23-26.

[18] Gupta, M. Narasimhan, S. G. and Schechner, Y. Y. 2008. On Controlling Light Transport in Poor Visibility Environments. *IEEE Conference on Computer Vision and Pattern Recognition*. 1-8.

[19] Ibrahim K. Msallam, Sea World. The Cement Freighter Wreck–Batroun. Available at: http://seaworldblog.wordpress.com/2013/08/ [accessed 9 March 2014].