Analysis of the Experimental Result Underwater Imaging

Jiang Xingfang[1, 2, a*], Zhang Rei[1,b], Huang Zhengyi[3,c], Zhou Hanyu[1,d]
1) School of Mathematics and Physics, Changzhou University, Changzhou213164, China,
2) State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Hangzhou 310012, China
3) Huaide College, Changzhou University, JingJiang214513, China,
a,xfjiang@cczu.edu.cn, b,rzhang@cczu.edu.cn, c,hzy@cczu.edu.cn, d,hyzhou@cczu.edu.cn
*Corresponding author

Abstract: For finding the changing law that the interaction between the photons and the water, the experiment has been finish and the result has been analyzed. There are a circle with five colors those are red, white, black, cyan, and yellow under the bottom of the wastepaper basket. The height of the wastepaper basket is 0.5m. The circle is shot by move phone. The image that shot underwater 0.01m is original image. The image that shot under water is distortion image. The distortion images are enhanced by Advanced Multiscale Retinex with different time's standard deviation cutting out. The enhancement method is based on the Gauss function with *k* time's standard deviation. For the every image of underwater imaging, the *k* is between 0.2 and 3.0 and the step is 0.2. The enhanced images are different from the original image for every pixel. The curve that is between the root-mean-square with the *k* time's standard deviation cutting out has minimum value. The root-mean-square is between the enhanced images and the original image for every pixel. For the sequence the minimum value is in different *k*. The first result shows the deeper the water depth is, the bigger the *k* is. The depth of water is from 0.02m to 0.36m, the *k* is from 1.2 to 3.0. Another result shows the deeper the water depth is, the flatter the curve is when *k* is bigger.

Keywords: Underwater Imaging; Advanced Multiscale Retinex; standard deviation; root-mean-square
OCIS: 100.2980

1 Introduction

With the land resource has been developed highly the oceanic resource and its button resource are developing. At the same time the observation research for the ocean such as the global carbon circulation, global climate change has been put forwarded [1]. The underwater detection technique has been the third hot points with space technology and oceanic technology [2]. The reference [3] has introduced for analyses the law of underwater imaging based on angular distribution estimation method of multiply scattered photons. The reference [4] analyzed the three defects under water imaging and the enhanced method. This topic is based on an experiment and the experiment is with a circle that forms five colors under the bottom of the wastepaper basket. The depth of the circle underwater is 0.02m to 0.36m and the circle shot. The sequence images are enhanced by Advanced Multiscale Retinex that put forwarded by author [5] and the results are got.

2 Theory

2.1 The interaction between the photons and water

The intensity of the incident light is I_0, the depth of the medium is d, as shown in Figure1. It took the infinitesimal length $r \sim r + \mathrm{d}r$, and the corresponding intensity is $I \sim I + \mathrm{d}I$. Here is

$\mathrm{d}r > 0$ and $\mathrm{d}I > 0$. Then is $(I + \mathrm{d}I) - I = -\alpha I \mathrm{d}r$, $\int_{I_0}^{I} \frac{\mathrm{d}I}{I} = \int_0^r -\alpha \mathrm{d}r$. The integral result is

$$I = I_0 \mathrm{e}^{-\alpha r} \tag{1}$$

The transmission intensity of the light is as exponential function.

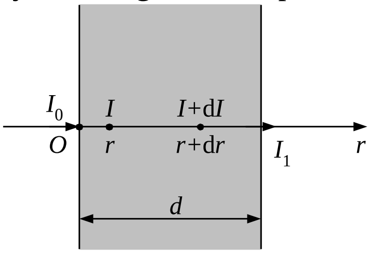


Figure 1. The transmission intensity through the medium

2.2 Advanced Multiscale Retinex

The Single-Scale Retinex is algorithm that the image $I(x, y)$ is decomposed into reflection image $R(x, y)$ and the incidence image $L(x, y)$. It is said [6-7]

$$I(x, y) = L(x, y) \times R(x, y) \tag{2}$$

and shown in figure 2.

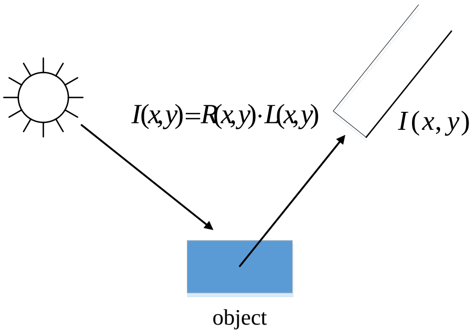


Figure 2. The basic idea of Retinex **Figure 3. Scene**

The incidence image $L(x, y)$ is estimated with the convolution between the function $F(x, y)$ and the image $I(x, y)$.

$$\hat{L}(x, y) = F(x, y) * I(x, y). \tag{3}$$

The function $F(x, y)$ is a Gauss function

$$F(x, y) = K \cdot \exp[\frac{-(x^2 + y^2)}{\sigma^2}], \tag{4}$$

Here parameter k is a normalization parameter and it is fitted

$$\iint F(x, y)\mathrm{d}x\mathrm{d}y = \iint K \cdot \exp[\frac{-(x^2 + y^2)}{\sigma^2}]\mathrm{d}x\mathrm{d}y = 1. \tag{5}$$

The parameter σ is standard deviation in Gauss function.

For solving the color distortion problem the Multiscale Retinex was put forwarded. It took three different standard deviations like 5, 150, 250 and for different color channels with different weight.

The Advance Multiscale Retinex is took different time's standard deviations cutting out like k=0.8, 1.2, 1.6 and so on [5] based on Gaussian distribution.

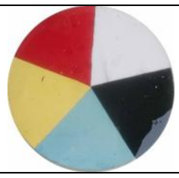
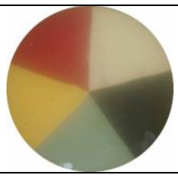
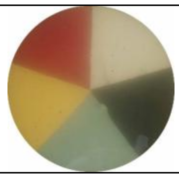
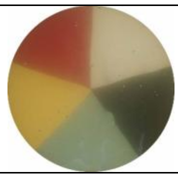
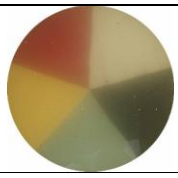
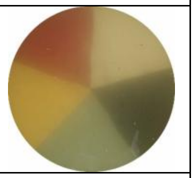
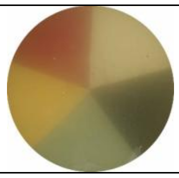
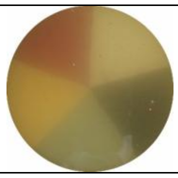
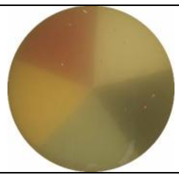
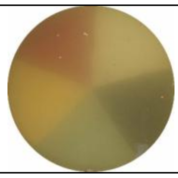
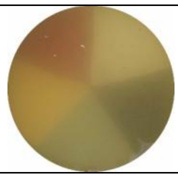
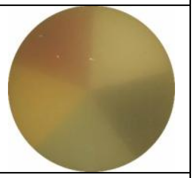
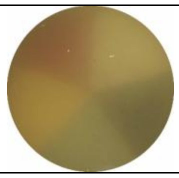
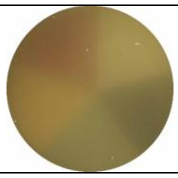
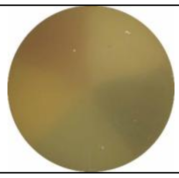
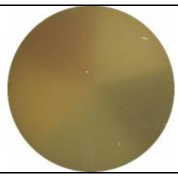
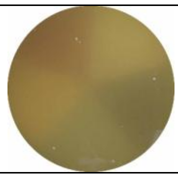
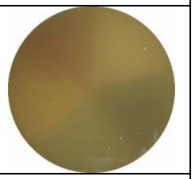
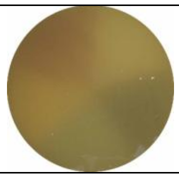
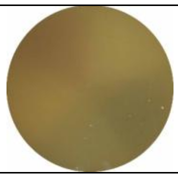
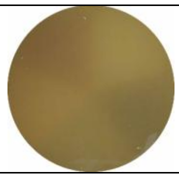
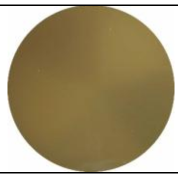
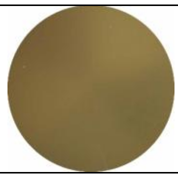
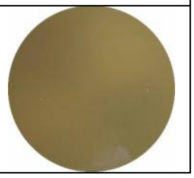
3 Experiments

The transmission process of the light under water includes three aspects. The images under imaging includes that the first one is the light is absorbed and scattered, the second one is the fore scatter light, and the third one is the back scatter light.

3.1 Prepare

The experiment device includes the wastepaper basket, color paper, adhesive tape, pen, dividing ruler, glue, umbrella, bucket, moving phone and holder, sponge, and so on. The sence is shown in figure 3.

Table 1. The images with the depth of underwater (Unit: m)

0.01	0.02	0.03	0.04	0.05	0.06
					
0.07	0.08	0.09	0.10	0.11	0.12
					
0.13	0.14	0.15	0.16	0.17	0.18
					
0.19	0.20	0.21	0.22	0.23	0.24
					
0.25	0.26	0.27	0.28	0.29	0.30
					
0.31	0.32	0.33	0.34	0.35	0.36
					

A circle is composed the papers. The color papers are red, white, black, cyan, and yellow. Each paper is a sharp of fan and the central angle is 70 degree, and the radius is 0.1m. The circle is under the bottom of the wastepaper basket shown in figure 3. There are three scale marks in the wastepaper basket at the position of the central angle is 120 degree, 240 degree, and 360 degree. The scale marks is for the bottom of the wastepaper basket in horizontal position. The moving phone is fixed the holder and the holder is fixed with wastepaper basket for shooting. The umbrella is for avoiding the reflection light of sunlight from water surface. The images are marked the depth of underwater like 0.01, 0.02, … and they express 0.01m, 0.02m, …underwater shown in Table 1.

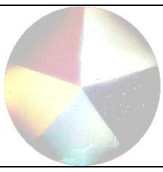
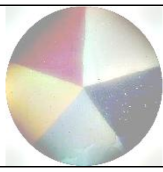
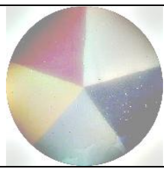
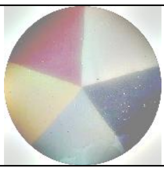
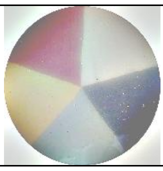
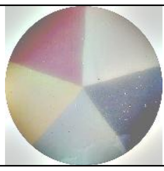
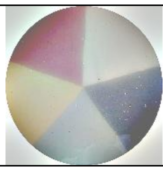
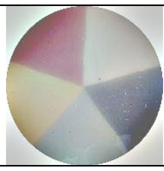
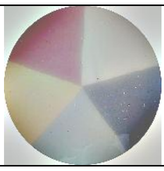
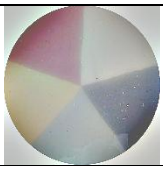
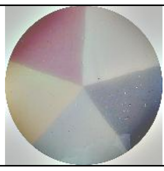
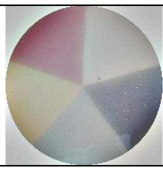
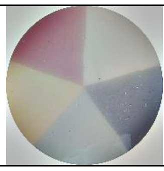
3.2 Image enhancement based on Advanced Multiscale Retinex

In the sequence images, the image its depth is less than 0.15m is clear. The image its depth is 0.17m is chosen as example and the image is enhanced by Advanced Multiscale Retinex with 0.2, 0.4, 0.6, …, 3.0 times standard deviation cutting out shown in Table 2. The root-mean-squares between the enhanced images and original image that is shot underwater 0.01m shown in Table 2 and the root-mean-square is defined as

$$\text{Sigma} = \sqrt{\frac{\sum_{j=1}^{n}\sum_{i=1}^{m}\left(I_1(i,\,j) - I_{17}(i,\,j)\right)^2}{m \times n}}\,. \tag{6}$$

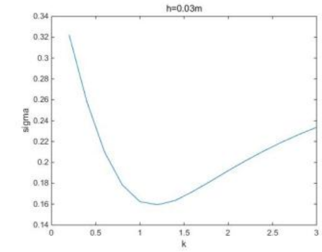
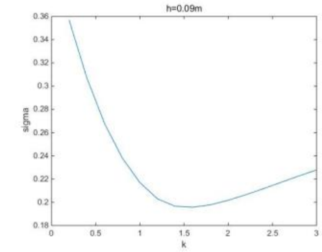
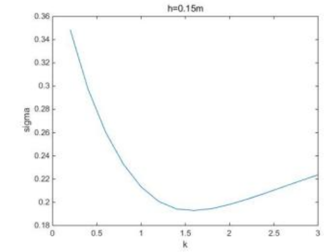
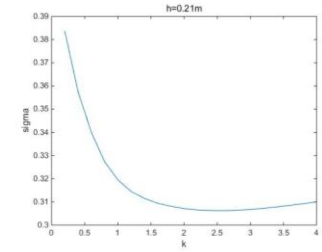
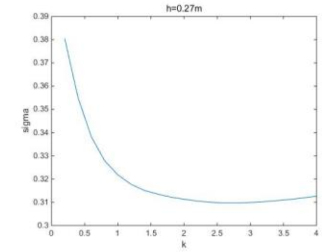
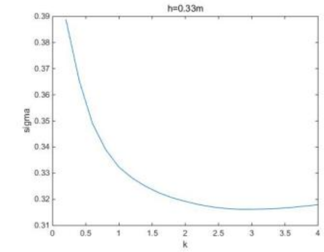
Here n is the row of the image and m is the column of the image. The symbol $I_{17}(i,\,j)$ expresses the image that shot underwater 0.17m and the pixel value at red channel with i row and j column. The symbol $I_1(i,\,j)$ expresses the image that shot underwater 0.01m and the pixel value at red channel with i row and j column. The bright of the image that shot underwater 0.17m is enhanced with the k time's standard deviation cutting out is shown in Table 2.

Table 2. The enhanced image that shot underwater 0.17m and their parameters

k	0.2	0.4	0.6	0.8	1.0
Enhanced image					
Sigma	0.3536	0.3037	0.2662	0.2397	0.2225
k	1.2	1.4	1.6	1.8	2.0
Enhanced image					
Sigma	0.2133	0.2089	0.2083	0.2097	0.2127
k	2.2	2.4	2.6	2.8	3.0
Enhanced image					
Sigma	0.2164	0.2207	0.2251	0.2296	0.2340

The relations between the Sigma of the images that shot underwater from 0.02m to 0.36m with the k are shown in Table 3.

Table 3. The relations between the images that shot underwater from 0.03m to 0.33m with the k

0.03	0.09	0.15
		
0.21	0.27	0.33
		

The minimum value of the curve is corresponding to the best *k* time's standard deviation cutting out. The relationship is shown in Table 4.

Table 4. the images shot underwater with the best k

Depth / m	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
best *k*	1.2	1.2	1.4	1.4	1.4	1.6	1.6	1.6
Depth / m	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17
best *k*	1.6	1.6	1.6	1.4	1.6	1.6	1.6	1.6
Depth / m	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25
best *k*	1.6	1.6	2.2	2.6	2.6	2.6	2.8	2.8
Depth / m	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33
best *k*	3.0	2.8	2.8	2.8	2.8	2.8	2.8	3.0
Depth / m	0.34	0.35	0.36					
best *k*	3.0	2.8	3.0					

4 Conclusion

For the images of underwater imaging, the deeper the water depth is, the less the definition is. The interaction between the photons and water is very complex in the transmission process. The image that imaging is shot underwater 0.01m is original image.

There are minimums for the sequence that the images underwater imaging with the depth is deeper and deeper is enhanced by advance Multiscale Retinex. The enhancement method is based on the Multiscale Retinex with different *k* time's standard deviation cutting out in Gauss function. For the every image of underwater imaging, the *k* is between 0.2 and 3.0 and the step is 0.2. The enhanced images are different from the original image for every pixel. The curve that is between the root-mean-square with the *k* time's standard deviation cutting out has minimum value. The root-mean-square is between the enhanced images and the original image for every pixel. For the sequence the minimum value is in different *k*. The first result shows the deeper the water depth is, the bigger the *k* is. The depth of water is from 0.02m to 0.36m, the *k* is from 1.2 to 3.0. Another result shows the deeper the water depth is, the flatter the curve is when *k* is bigger.

Acknowledgement

This paper authors express their sincere thanks to the reviewer for suggestions and comments. This work was supported by open issues of State Key Laboratory of satellite Ocean Environment Dynamics (No. SOED1503).

References

[1] Ling Zaiying. Modeling the bidirectional reflectance distribution function of water based on Monte Carlo simulation [D]. Master's degree dissertation of Zhejiang University. 2007

[2] Hu zhigang. The research of underwater 3D positioning technique based on binocular stereo vision [D]. Master's degree dissertation of Zhongguo ocean University. 2011

[3] Li Shengfu, Chen Guanghua, Wang Rongbo, et al. Monte Carlo based angular distribution estimation method of multiply scattered photons for underwater imaging [J]. Optics Communications. 2016, 381: 43-47

[4] Li Xinlu. Analysis Simulation of the three defects and Research of the Image Enhancement Method for Underwater Imaging [D]. Master's degree dissertation of Changzhou University. 2017

[5] Jiang Xingfang. The study and its application of the method of moving cloud in remote sensing image [M]. Germany: JinLang Press. 2016

[6] Zhou Hanyu. Underwater image enhancement method based on Advanced Multi-Scale Retinex [D]. Changzhou University. 2018

[7] Xie Fengying, tang Meng, Zhang Rui. Review of image enhancement algorithms based on Retinex [J]. Journal of Data Acquisition and Processing. 2019, 34(1): 1-11