New approach for underwater image denoise combining inhomogeneous illumination and dark channel prior

Zitao Wang
Department of Electronic Engineering
Ocean University of China
Qingdao, China 266100
Email: m23schofield@gmail.com

Bing Zheng*
Department of Electronic Engineering
Ocean University of China
Qingdao, China 266100
Email: bingzh@ouc.edu.cn

Weijian Tian
Academy of Opto-Electronics
Chinese Academy of Science
Qingdao, China 266100
Email:tianweijian@sina.com

***Abstract*—The clarity of underwater image is significant for underwater research. But due to the absorptive and scattering nature of seawater, underwater images are essentially characterized by their poor visibility. How to get a clear image is hot issue. And there are two problems in underwater clear vision area: getting clear original image and image processing. In this paper we developed a new approach technology to solve these problems. In the first place we developed an inhomogeneous illumination method to get the clear original image, then the dark channel prior method was used to process the original image. The processed image is with high resolution and definition.**

I. INTRODUCTION

The characteristic of underwater image is different with it in the air area. The light attenuation process is caused by absorption (which removes light energy) and scattering (which changes the direction of light path). Due to the greatly attenuation and high backscatter noise the underwater vision is with poor visibility, low resolution and poor contrast. There are two mainly problems in underwater image process: how to get clear original image and how to process it.

For the first question the main subject of underwater target detection is to decrease the backscattering effectively. One of the attractive solutions is the use of laser as illumination source (such as techniques of synchronous scanning and range-gated). And it can effectively decrease the backscattering and increase the visible distance[1]. But the laser approach is based on depressing single-way scattering. Theoretically there exist multi-way scattering during the light transmission, and a large blind area in laser detection. In this paper a new inhomogeneous illumination method is developed, which can decrease the strong backscattering and increase the detection. By the proposed method, underwater target detection with wide FOV, low backscattering noise (especially through turbid water) and non-blind area.

For the another question the main method is simulated or measure the PSF and MTF of seawater and used Wiener filters to restore the blurred underwater images.[2]. Such methods was need a large number of underwater experiment or analog simulation. And the simulated or measure result is not universality. In this paper we use the dark channel prior method to process the underwater image. The processed result is clearly and with high resolution and definition.

II. GET CLEAR ORIGINAL IMAGE: INHOMOGENEOUS ILLUMINATION METHOD

The key problem in getting clear underwater original imaging is to overcome backscatter effect. Under the normal illumination condition high power in the close range engender great backscatter and low power in the far distance limit detection range.

To solve this problem, we propose using an inhomogeneous illumination field where the power density is inversely proportional to the light attenuation in water. With such inhomogeneous illumination field, the backscattering light is weak at short range because of the low power density of illumination, while the light power density occurs at large range, but the scattering light will be attenuated during the transmission and become too weak to be detected by the receiver.

According to the theory of inhomogeneous illumination field, illumination power density is distributed inversely proportional to the rule of the light attenuation in water medium.

The power received by the receiver is :

$$P = \frac{1}{4} P_0 \left[\frac{D}{r(X,Y,Z)} \right]^2 e^{-\alpha 2 r(X,Y,Z)} \tag{1}$$

where

P	the power received by the receiver
P_0	source power
D	size of receiver
α	attenuation parameter
$r(X,Y,Z)$	distance between target point and receiver

According to the theory the illumination power density $E(X,Y,Z)$ is inverse of the equation (1).

The illumination power density expression is shown as below:

$$E(X,Y,Z) = C \bullet \left[\frac{r(X,Y,Z)}{D} \right]^2 e^{\alpha 2 r(X,Y,Z)} \tag{2}$$

Where

c the constant parameter

And the realization of the inhomogeneous illumination field is shown in Figure.1.

In such illumination field, the power received at long distance is approximately as same as those at short distance.

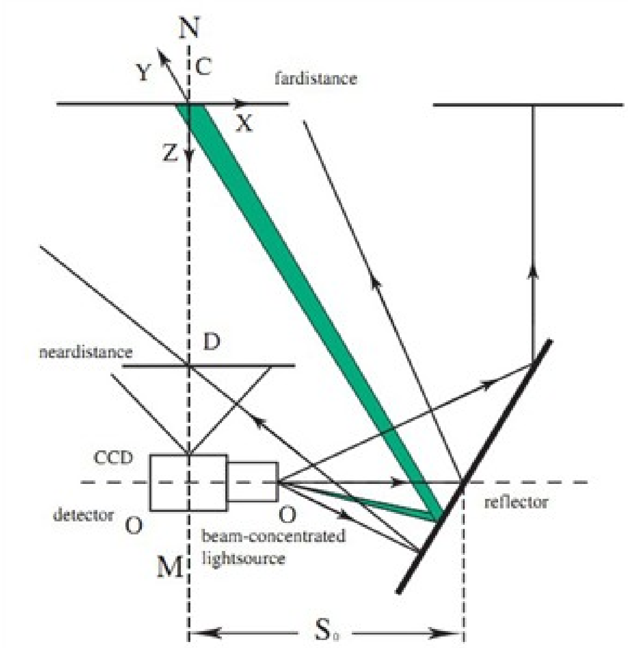

Fig. 1: The optical axis of the beam-concentratedillumination source(OO) is set horizontally and denote O the origin of the system. A reflector is place along OO at a certain distance to the light source. A camera is set up at O which detection orientation MN is vertical to OO.

III. Image processing: dark channel prior method

A. Physics of underwater light

In order to deal with underwater image processing, we have to consider the basic physics of underwater light. The underwater light attenuation equation is similar to atmosphere. According to McCartney model[3], imaging model is like follows:

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{3}$$

Where the I is observe intensity, J is the scene radiancem, A is the underwater light, and t is the water transmission.

$$t(x) = e^{-(a+b)d(x)} \tag{4}$$

Where is a is absorption coefficient, b is scattering coefficient, $d(x)$ is scene depth.

B. Dark channel prior

According to He′s research[4], in most of clear images, at least one color channel has very low intensity at some pixels[4]. and he has count more than 50000 images, the statistics of dark channels as shown in Figure.2.

As shown in Figure.3, that about 75% of the pixels in the dark channels have zero values, and the intensities of 90% of the pixels are below 25%[4]. so that if it can be used in the underwater images, the result of processed will have high visibility.

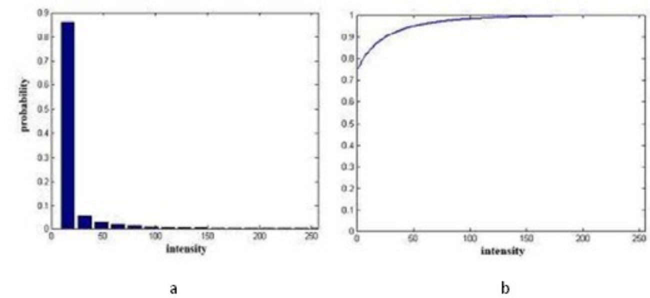

Fig. 2: Statistics of the dark channels. (a) histogram of the intensity of the pixels in all of the 5000 dark channels. (b) corrseponding cumulative distribution.

C. Dark channel prior algorithm

The algorithm flow chart is shown as Figure.3. As shown

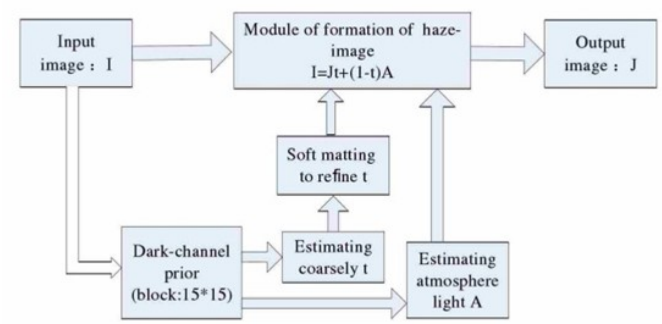

Fig. 3: The algorithm flow chart of dark channel prior.

in equation (3), the original images is I, the real image is J, the water transmission is t. In order to restore the image, we define the dark channel is:

$$J^{dark}(x) = \underset{c\in(r,g,b)}{min}(\underset{y\in\Omega(x)}{min}(J^c(y))) \tag{5}$$

Where the J^c is a color channel of J and Ω is a local path centered at x.

The next step is simulate the water transmission $t(x)$:

$$\begin{aligned} \underset{c}{min}(\underset{y\in\Omega(x)}{min}(\frac{I^c(y)}{A^c})) &= t^{'}(x)\underset{c}{min}(\underset{y\in\Omega(x)}{min}(\frac{J^c(y)}{A^c})) \\ &+ (1 - t^{'}(x)) \end{aligned} \tag{6}$$

On the right of the equation (6), the dark channel of real image is approximately equal zero. So that the water transmission $t(x)$ is :

$$t^{'}(x) = 1 - \omega\underset{c}{min}(\underset{y\in\Omega(x)}{min}(\frac{I^c(y)}{A^c})) \tag{7}$$

Where ω is a constant parameter $(0 < \omega < 1)$.

Then we used the bilateral filtering method[5] to refine the transmission.

The last step we recovering the scene image:

$$J(x) = \frac{I(x) - A}{max(t(x), T)} + A \tag{8}$$

The T is a lower bound. And used underwater optical theory to determine the A.

IV. EXPERIMENT

A. Experimental Facilities and Image Capture

The experimental facilities is shown as Figure.4.

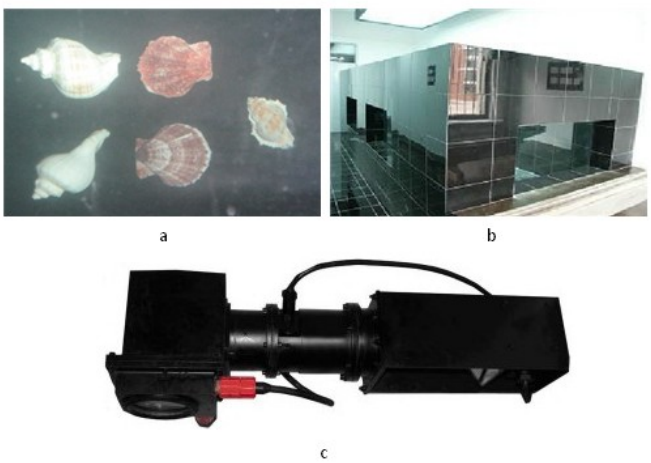

Fig. 4: (a) the target, (b) experiment pool, (c) underwater detecion system.

When the transparency (measured by Duntley law) is $1.41m$ and target is at distance of $2.25m$ (1.6 times visibility), the plane is distinguishable with obscurity.

And we use normal illumination image system and inhomogeneous illumination image system to capture the image in same distance(the power of illumination source is equal) and it shown in Figure.5-Figure.7.

As shown in Figure.5 we can see that at the 0.6 time of visibility distance, the observed resolution of normal illumination image is difficult to distinguish but the observed resolution of inhomogeneous illumination image have a significant improvement.

As shown in Figure.6 we can see that at the 1 time of visibility distance, the contour of normal illumination image is ambiguous but the observed resolution of inhomogeneous illumination image still can distinguish.

As shown in Figure.7 we can see that at the 1.64 times of visibility distance, the normal illumination image is already unrecognized but the contour of inhomogeneous illumination image can distinguish clearly.

Obversely the inhomogeneous illumination image is more clearly than the normal one. But it still can not satisfy high requirement.

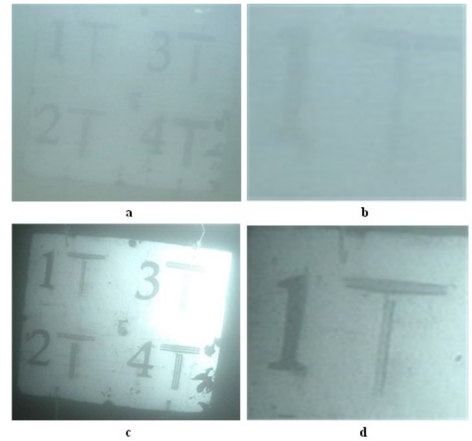

Fig. 5: (a)(b) Transparency is $1.41m$ and target distance is $1.41m$ (0.6 time of visibility), the normal illumination image is ambiguous. (c)(d) Transparency is $1.41m$ and target distance is $1.41m$ (0.6 time of visibility), the observed resolution is 1mm from the inhomogeneous illumination image.

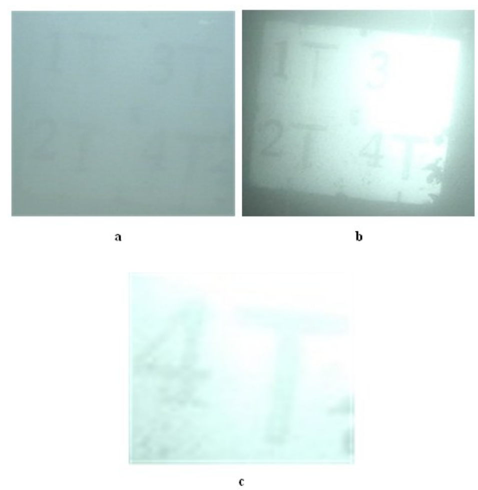

Fig. 6: (a) Transparency is $1.41m$ and target distance is $1.41m$ (1 time of visibility), the normal illumination image is ambiguous. (b)(c) Transparency is $1.41m$ and target distance is $1.41m$ (1 time of visibility), the observed resolution is 4mm from the inhomogeneous illumination image.

Fig. 7: (a) Transparency is $1.41m$ and target distance is $2.31m$ (1.64 times of visibility), we could not observe the target from the normal illumination image. (b) Transparency is $1.41m$ and target distance is $2.31m$ (1.64 times of visibility), the inhomogeneous illumination image is ambiguous but the target is discernible.

B. *dark channel prior image process*

The dark channel prior algorithm is used to processed the inhomogeneous illumination image. And the result is shown as Figure.8-Figure.10.

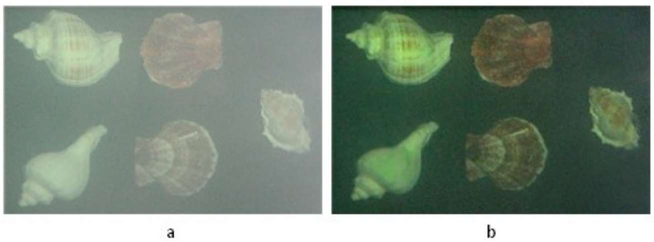

Fig. 8: The transparency is 70cm and the target distance is 0.6 time of visibility, the original image is shown in the left and the processed image is shown in the right.

Fig. 9: The transparency is 70cm and the target distance is 1 time of visibility, the original image is shown in the left and the processed image is shown in the right.

Fig. 10: The transparency is 70cm and the target distance is 1.6 times of visibility, the original image is shown in the left and the processed image is shown in the right.

It is obversely that the contrast and definition of processed image is get great improvement. And the texture of the processed image is clearly, the backscattering noise of the processed image is removed. It can be able to stand the proof that the underwater dark channel prior algorithm is powerful and effective.

V. Conclusion

In this paper, a simple and effective method was presented to restore underwater image in poor visibility.

The inhomogeneous illumination method has been realized, and the ocean optics theory is used to improve the dark channel prior algorithm.

And The experimental results show that the inhomogeneous illumination method to get brilliant underwater original image is effectively and powerful, and the improved dark channel prior algorithm can remarkable remove the backscattering noise and enhance the contrast and definition.

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