Underwater image color correct in extremely poor visibility

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Abstract:

In this paper, a new approach to realize underwater image color correction is proposed. The key problem of low visibility underwater vision is backscatter noise and color degradation. In order to solve this problem, we use color image histogram equalization to process the images taken by inhomogeneous illumination which intensity distribution was an inverse form of light attenuation pattern. The image obtained from turbid water become clear owing to inhomogeneous illumination and become colorful owing to color image histogram equalization which separate three color channels into three gray images. Experiment result decrease the backscattering effect and get a color-corrected image using this approach.

Keywords-inhomogeneous illumination, color image histogram equalization, back scattering, color correction.

I INTRODUCTION

Underwater image is plagued by poor visibility and color degradation. High quality and colorful image is strongly needed in underwater research.

Generally, light absorption and scattering are the main problems in underwater imaging[1]. Due to selective absorption by water molecule, the red light reduced heavily when the depth increased slowly, only green-blue light (wavelength is about 0.5um) can stay partly. This is why the underwater image is always bluish. In the sea, the red light is gone by 3m, the orange light is gone by 5m, and the yellow light is gone by 10m, at last, only blue light remains in the sea after 25m[2]. On the other hand, due to back scattering caused by suspended particles in the sea, underwater image is of poor visibility or even of extremely poor visibility in very turbid condition.

There already exist some mature technologies to handle this problem so far. A method was proposed to eliminate back scattering effect and to get a better underwater vision, but the algorithm is complexity and based on a couple of images taken through a polarizer at different orientations[3]. Another method used for color correction of underwater images is a learning-based method use the relationship between color depleted image and color corrected image. But this method can not work in extreme turbid water[4]. Recently, a perceptual adaptive illumination is used to realize color correct, but it can just work when the target is in a certain distance, lacking of flexibility[5].

In this paper, inhomogeneous illumination is used to get a clear image firstly[6]. Inhomogeneous illumination can decrease back-scattering effectively, so that a clear image is obtained.

On account of the underwater image taken with inhomogeneous illumination can only decrease the back scattering effectively, the image is still lack of color information and bluish. In order to realize image color correction, color image histogram equalization[7] is used in this paper. We used inhomogeneous illumination to get a clear image in low visibility water, and then used color image histogram equalization to process the color degenerated image.

II METHOD

In this paper, we use inhomogeneous illumination to get a clearer image, then process it use color image histogram equalization to get more color information to realize color correction. The output result is vivid and colorful.

A. Inhomogeneous Illumination

According to McCartney model[8], imaging model is like follows:

$$E(d,\lambda) = E_0(\lambda)e^{-\beta(\lambda)d} + E_\infty(\lambda)(1-e^{-\beta(\lambda)d}) \quad (1)$$

In the right of eq(1), the first term is called attenuation and the second term is caused by scattering. In this equation, d is the scene depth, λ is the light wavelength, and the β is the scattering coefficient, is the observed light intensity, $E_0(\lambda)$ is the scene radiance. $E_\infty(\lambda)$ is the light in the environment. Inhomogeneous illumination can compensate the intensity in the first term and can decrease the back scattering effect in the second term.

The inhomogeneous illumination light energy is not evenly distributed, low energy density light occurred at short range is to decrease the back scattering effect as small as possible, and high energy density light occurred at large range is to increase the target signal intensity. The energy distribution of concentrated light is shown in Fig. 1.

The intensity in the center of light resource is strong enough, while, the intensity at the edge region is extremely low.

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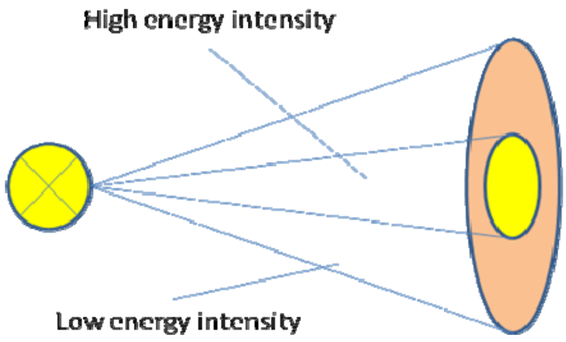

Fig1. construction of The concentrated light

Additional, The receiver used in this experiment is a CCD sensor with 5 mega-pixel. This inhomogeneous illumination technology can not only decrease back scattering, but also has advantages in getting a large viewing angle.

The relationship among the target, receiver and light source is shown in figure 2.

The illumination at target A is :

$$E_A = \frac{1}{R^2} e^{-cR} \tag{2}$$

The receiver received the intensity of A:

$$E_{receiver} = \frac{I_A}{L^2} e^{-cL} \tag{3}$$

E_A is the illumination at A; I is the intensity of light source; R is the distance from light source to target; c is the volume attenuation coefficient. $E_{receiver}$ is the intensity at receiver plane. L is the distance from target A to receiver. I_A is the intensity at the target.

In formula 2, we can see that the light in underwater is attenuated exponentially with intensity. If the light source is not strong enough, the intensity of target will present very weak. It is necessary to use inhomogeneous illumination as light source.

In this paper, the underwater transparency is 0.7m. In 0.5 time visibility distance, a fuzzy and colorless image was captured with normal illumination, but, a clear image was captured using inhomogeneous illumination.

B. *Color Image Histogram Equalization*

There has already existent a relative mature histogram equalization method based on cumulative probability function to process gray image. The basic idea of histogram equalization is transfer the histogram of original image to evenly distributed form. This increase the dynamic range of gray pixel values, so that enhance the image contrast. If histogram equalization used to process the original images directly, the output image will become gray which will lose a lot of color information. The image processed in this experiment is colorful, so color image histogram equalization is used to realize color correct[7].

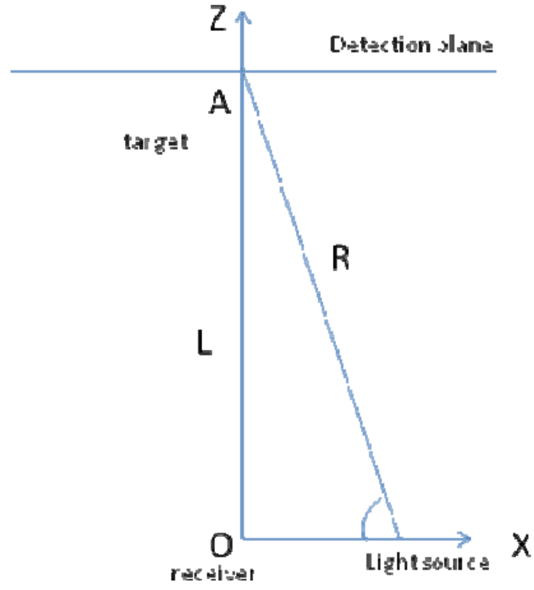

Fig 2. structure of light source, target and receiver

Every pixel in color image has three color channels, that is RGB(red, green, blue). The color image has three-dimension rather than one-dimension, which can be described as follows:

$$Z_{rgb} = [Z_r, Z_g, Z_b]^T \tag{4}$$

Z_r, Z_g, Z_b represent red channel image, green channel image, and blue channel image respectively, so that every image can be regarded as gray image. Each channel is histogram equalized by a monotonically increasing gray level transform later on. Then combine these three images after histogram equalization respectively.

The output image has high contrast and many color information. While, this method is based on independent equalization without consider the relationship among RGB three channels, which will lead little color distortion. But the significant achievements are the short time of processing it and the simple algorithm.

III EXPERIMENTAL RESULT

In our experiment, a method called Duntley rule which was proposed by Koschmieder is used to obtain underwater transparency value[9]. This method use black board instead of white one, and put it in the same deep position as receiver, moving the black board and looking at it in a horizontal way through inspection window until lose sight of it. Underwater transparency value is inferred by the distance from this location of black board to inspect window. In this paper, the underwater transparency is 0.7 m, that means the visibility distance is 0.7 m. The distance between target and receiver is half of visibility distance(0.5 time visibility distance that is 0.35 m).

The experiment result is presented in two parts. In the first part, some underwater pictures on the web were used to test using color image histogram equalization. In the second part, show the underwater pictures acquired by our technology.

(a)

(b)

(c)

Fig. 3. (a) original image on the web. (b) image using white balance algorithm. (c) image using color image histogram equalization

Part 1

In order to find the method is available in underwater imaging, we test two pictures on the web firstly.

The first group pictures are shown in figure 3.

In figure 3, the original image is bluish obviously. After white balance, the water color in this image is blue, while the chair is still dim and bluish. The image processed after color image histogram equalization is colorful, the color of the chair is real see with human eyes.

The second group pictures are shown in figure 4.

In figure 4, the original image is still bluish. In this group the image process after white balance is worse than the original image see with human eyes. However, the colors in image which processed after color image histogram equalization are high contrast.

It is obviously to see that the image processed by color image histogram equalization is colorful and more vivid. As with the result is close to reality with human eyes, this technology is available in processing underwater images, so we carry out the experiment to test the image taken under inhomogeneous illumination.

(a)

(b)

(d)

Fig. 4. (a) original image on the web. (b) image using white balance algorithm. (c) image using color image histogram equalization.

Part 2

In our pool experiment, the transparency was 0.7 m. Under such an extremely poor visibility environment, it is hardly to see anything clearly in water by human eyes.

(a)

(b)

(c)

(d)

Figure 5. (a) The image in clear water with nature light. (b) the image using normal illumination in 0.7m underwater transparency. (c) the image using inhomogeneous illumination in 0.7m underwater transparency. (d) the color corrected image.(all the distance between target and receiver is 0.35m

The method in this paper can get a relatively better quality image. The result was shown in figure 5. The original image in clear water under nature light was shown in figure5(a). The fuzzy image under normal illumination in 0.7 m transparency was shown in figure5(b). The clear image under inhomogeneous illumination in 0.7 m transparency was shown in Figure5(c). The color corrected image using color image histogram equalization and with a lot of color information was shown in Fgure5(d).

As shown in figure 5, the target we use is a moon cake cover. In such a close distance, the image is dim with nature light even in clear water. When in 0.7m transparency condition, it is hard to see the target details using nature light, let alone colors. Target is become fuzzy and lose a lot of information even use extra normal illumination. However, the color is retained well by using inhomogeneous illumination which can improve the visibility to a great extent. The figure 5(c) in turbid water is brighter than the figure 5(a) which is obtained in clear water. Finally, the color of the image after color image histogram equalization is approach to the real color in air.

IV Conclusions

In this paper, we present a simple and effective method to realize underwater image color correction in extremely poor visibility.

Inhomogeneous illumination can decrease back scattering effectively, and color image histogram equalization is a simple and effective method to realize color correction of color images.

The experimental results show that this method can enhance the contraction and the color of underwater images well. In further work, the relationship between RGB channels of a pixel can be considered to get a better color corrected image.

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