

A Underwater Image Enhanced Algorithm combined MSR and Channel Energy

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Abstract— Vision is the most important source of information for Unmanned Underwater Vehicle(UUV), only a clear image can make it possible for a UUV to operate automatically, Due to strong absorption and light scattering for water, the image of underwater imaging has a serious degradation, whether in distance or in quality. Based on classical Retinex theory, this paper proposed an underwater image enhanced algorithm. For different channel of underwater image has apparently different energy, especially green channel has overwhelming power than others, we added a step to energy balance of the RGB three channel in classical Multi-Scale Retinex (MSR). Experiment data show that, compared to the traditional three-channel simple addition, our improvement can get more natural recovered underwater image.

Keywords—Channel energy , Enhanced algorithm, Improvement, MSR, Underwater image

I. INTRODUCTION

Light scattering and color change are two major sources of distortion for underwater photography. Light scattering is caused by light incident on objects reflected and deflected multiple times by particles present in the water before reaching the camera [1]. This in turn lowers the visibility and contrast of the image captured. Color change corresponds to the varying degrees of attenuation encountered by light traveling in the water with different wavelengths, rendering ambient underwater environments dominated by a bluish tone. No existing underwater processing techniques can handle light scattering and color change distortions suffered by underwater images, and the possible presence of artificial lighting simultaneously

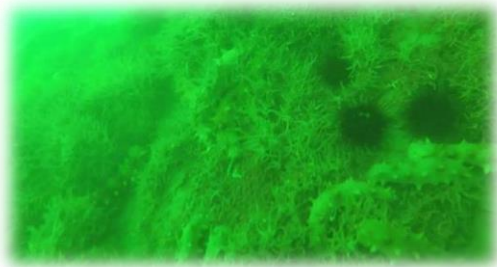


Figure 1. Typical Underwater image

Due to strong absorption and light scattering for water, the image of underwater imaging has a serious degradation, whether in distance or in quality, in particular the scattering which makes the underwater images contrast sharply decreased and result in serious blur. Therefore, in order to be

able to obtain the effective features of the sea urchin in the future, the acquired image must be enhanced. The underwater captured image is shown in Fig. 1(a) below. There are mainly 3 classes of underwater image enhancement method:

- Image enhancement algorithms based on spatial domain, such as Contrast Stretching, Equalization of Histogram, etc.
- Image enhancement algorithms based on frequency domain, such as Homomorphic Filtering, Wavelet Transform, etc.
- Image enhancement methods based on color constancy theory, such as Automatic White Balance, Retinex algorithm [2, 3], and Dark Channel Prior defogging algorithm.

Among them, Retinex algorithm is regarded that has good effect in image fog removal. Considering underwater image has similar degrade cause with fog image, their quality are all highly susceptible to scattering, refraction, and reflection of a large amount of small particles in the air or water before the light reaches the camera lens, we adopt it in our algorithm to do image enhancement.

II. BACKGROUND KNOWLEDGE

The Retinex theory is the basis of an image enhancement method proposed by Jobson et al. [4, 5]. This method uses the theory of color constancy, and is a model that can be solved by mathematical calculation. It assumes that an ideal image can be expressed as:

$$I(x,y) = L(x,y) \cdot R(x,y) \quad (1)$$

Where $L(x,y)$ is the luminance component, which is independent of the scene and determines the dynamic range of the image, and $R(x,y)$ is the reflection component, which is independent of lighting.

In the 1990s, Jobson et al. [4,5] proposed the Single-Scale Retinex (SSR) algorithm based on a homomorphic filtering method. However, this method cannot address both dynamic range and tonal contrast, and a halo phenomenon can even appear. To overcome the limitations of SSR, the Multi-Scale Retinex (MSR) algorithm. However, MSR causes a larger color distortion. Subsequently, Rahman proposed the MSRCR algorithm, which addresses the color distortion of MSR. Basically, the MSRCR algorithm is an extension of the Retinex algorithm. It achieves a balance with respect to dynamic range, edge enhancement, and color constancy, and can adaptively enhance various types of images, which makes it suitable for a wide range of applications.

The Multi-Scale Retinex (MSR) can be compactly written as:

$$RMSR_i(x, y) = \sum_{n=1}^N w_n \cdot \{ \log[S_i(x, y)] - \log[S_i(x, y) * M_n(x, y)] \} \quad (2)$$

Where the subscripts $i \in (R, G, B)$ represent the 3 color bands, N is the number of scales being used, and w_n as the weighting factors for scales. The $M_n(x, y)$ are the surround functions given by:

$$M_n(x, y) = K_n \exp[-(x^2 + y^2)/\sigma_n^2] \quad (3)$$

where σ_n^2 are the standard deviations of the Gaussian distribution that determine the scale. The magnitude of the scale determines the type of information that the Retinex provides: smaller scales providing more dynamic range compression, and the larger scales providing more color constancy. The K_n are selected so that $\iint RMSR(x, y) dx dy = 1$. Each of the expressions within the summation in formula(1)(2) represents an SSR.

Note that the output images of MSR may have serious color distortion. To solve this, MSRCR is further proposed, which is expressed as follows.

$$RMSRCR_i(x, y) = C_i(x, y) * RMSR_i(x, y) \quad (4)$$

where $C_i(x, y)$ is the color restore function used to regulate the percentage of the three color channels. In MSRCR, $C_i(x, y)$ are unified set to 1/3, and many researchers did further work to find better method to set these three critical parameters.

Considering ocean water has different absorptivity for light of different wavelengths, that make 3 color bands of underwater image have different energy, it is obviously wrong to adopt classical MSRCR to do underwater image Enhancement by arbitrarily set all $C_i(x, y)$ to 1/3.

III. OUR IMPROVEMENT

In Formula (4), we redefined the weights using the content of the channel energy. It works as following:

Step1: In Formula (4), we count the sum of all pixel values Pt_i in all $RMSR_i(x, y)$.

Step2: In order to balance the power of each channel, reduce suppression effect of the background color on the overall picture, we redesigned $C_i(x, y)$ in formula (4) as formula (5) (6):

$$Mx = Max(Pt_i) \quad (5)$$

$$\begin{cases} C_i(x, y) = \frac{Mx}{Pt_i} * p \\ \sum_{i=1}^3 C_i(x, y) = 1 \end{cases} \quad (6)$$

Here, parameter p is a variable that implements the sum of C_i as 1

From formula(5)(6), we can see, The channel with weak energy is amplified to the same level as the channel with strong energy, that, this directly increases the amount of red absorbed by seawater to the energy level of blue absorbed by seawater.

IV. EXPERIMENT DATA

The experimental data is derived from the public data set provided by the China National Natural Science Foundation's underwater robot competition on website(in Chinese):

<http://www.urpc.org.cn/index.html>.

The dataset format is introduced on website (in Chinese):

<http://www.urpc.org.cn/a/js/2019/0805/125.html>.

Dataset can be downloaded from website:

<https://pan.baidu.com/s/1ZdEa3gbuguenXtM4iWrijQ> (password: pp10).

Figure2 (a) and figure3 (a) are original underwater images, figure2 (b) and figure3 (b) are enhanced output images by our proposed algorithm corresponding figure2 (a) and figure3 (a).

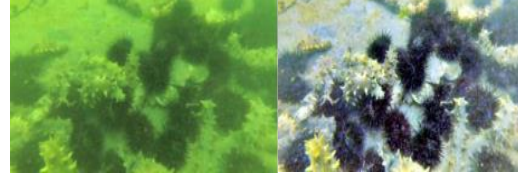


Figure 2.(a) Figure 2.(b)



Figure 3.(a) Figure 3.(b)

From figure2 (b) and figure3 (b), we obviously find that the green channel of the underwater image has been balanced, and the whole image is more natural, reasonable and rich in details. That means our work can well enhanced underwater image.

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