Underwater image enhancement algorithm based on Retinex and wavelet fusion

Underwater image enhancement algorithm based on Retinex and wavelet fusion

Junjun Chen[1], Zhengzhong Gao[1*], Chen Huang[1] and Lixing Yang[1]

[1] College of Electrical Engineering and Automation, Shandong University of Science and Technology, Qingdao, Shandong Province, 266590, China

[*]zzgao@sdust.edu.cn

[*]Corresponding author's e-mail: skdjun@163.com

Abstract. Aiming at the problems of color cast, low contrast and fuzz in the original underwater image, this paper proposes an underwater image enhancement algorithm based on Retinex and wavelet fusion. First, this paper uses the multi-scale Retinex algorithm to perform color correction processing on underwater images. Then, this paper performs gamma transformation and sharpening on the image to improve the contrast and sharpness of the image. Finally, this paper uses wavelet fusion algorithm for image fusion to obtain underwater images with clear textures and details. Through subjective and objective evaluation with other algorithms, the algorithm proposed in this paper improves the color cast and fuzz, and improves the contrast and clarity of the image.

1. Introduction

Underwater image processing is playing an increasingly important role in aquaculture, marine pasture monitoring and other fields [1]. As light propagates in water, different wavelengths of light have different absorption characteristics. At the same time, there are a large number of plankton and suspended particles in the water, which leads to the scattering effect of light when propagating in the water [2]. Therefore, the underwater original image collected by the camera usually has problems such as color cast, low contrast, and fuzz.

In view of the different problems of acquired underwater original images, many scholars have proposed methods to improve the quality of underwater images. Zhang et al. [3] used Retinex to perform color correction on underwater images, and then adjusted the illumination of the brightness channel to restore the real underwater scene. Subah et al. [4] decomposed the color-corrected and contrast-enhanced image into low-frequency components and high-frequency components through a three-scale wavelet operator, and reconstructed the final enhanced image through multi-scale fusion. Yang et al. [5] performed RGB three-channel energy balance on the multi-scale Retinex(MSR) processed image according to the energy difference of different channels in color images. Sanila et al. [6] proposed using white balance to preprocess the image, and then sharpened the processed image and equalized the histogram with limited contrast to obtain an enhanced image.

Since different types of underwater images have different problems, the above methods improve the contrast and clarity of underwater images to a certain extent. However, existing underwater image enhancement algorithms generally cause loss of image information. It is difficult to balance the relationship between image contrast and saturation. In view of the shortcomings of the algorithm, this paper proposes an underwater image enhancement algorithm based on Retinex and wavelet fusion. The specific process is shown in figure 1.

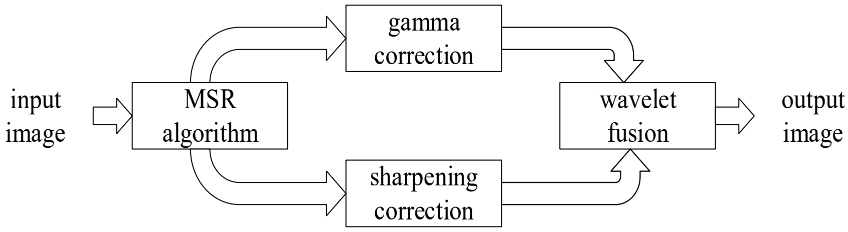

Figure 1. The framework of the proposed method paper.

2. Proposed method

2.1. MSR image enhancement algorithm

The idea of Retinex algorithm for image enhancement is to remove the influence of environmental brightness from the original image and solve the color characteristics of the object itself. In this way, the purpose of underwater image enhancement is achieved. The operation of Retinex theory in the logarithmic domain is closer to the visual characteristics of the human eyes [7]. And the multiplication operation can also be converted into a simple addition and subtraction operation, namely:

$$\log R(x,y) = \log I\left(x,y\right) - \log L(x,y) \tag{1}$$

In the formula, *I(x,y)* is the collected underwater image. *R(x,y)* is the reflection component containing the color information of the scene, reflecting the color characteristics of the object itself. *L(x,y)* is the illumination component of the image, reflecting the brightness of the target scene. Among them, the illuminance component *L(x,y)* is solved by the center wrap function:

$$L(x,y) = I(x,y) * G(x,y) \tag{2}$$

In the formula, * represents the convolution operation, and the center wrap function *G(x,y)* often uses the Gauss center wrap function.

The MSR algorithm is developed on the basis of the single-scale Retinex(SSR) algorithm. Its advantage is to maintain the saturation of the image and compress the dynamic range of the image [8]. In this paper, the MSR algorithm is used to process the collected original images.In this paper, the value of the reflection component is obtained at different scales, and then the value of the reflection component is weighted and averaged. The formula of MSR is:

$$\log R(\mathrm{x},y) = \sum_{n=1}^{N} \omega_n [\log I(x,y) - \log L(x,y)] \tag{3}$$

In the formula, *N* represents the number of scales, and ω_n represents the weighting factor.

2.2. Gamma correction and sharpening correction algorithm

In view of the low contrast and uneven brightness of underwater images, gamma correction is a nonlinear operation on the gray value of the input underwater image. After gamma correction, the gray value of the output image has an exponential relationship with the gray value of the input image [9]. The gamma correction formula is as follows:

$$I_{\text{out}} = AI_{\text{in}}^{\gamma} \tag{4}$$

In the formula, I_{in} is the input image, I_{out} is the output image, *A* is 1, and γ is 1.2.

In view of the blurring of underwater images, the sharpening correction algorithm makes the edges and textures of the image clearer. First of all, this paper will low-pass filter the original image to produce a dull and blurred image. Then this paper subtracts the original image from the blurred image to obtain an image that retains high frequency components. Finally, this paper superimposes the high-frequency image with the original image to produce an image with enhanced edges [10]. The formula is as follows:

$$y(m,n) = x(m,n) + (x(m,n) - z(m,n)) \tag{5}$$

In the formula, *x(m,n)* is the input image signal, *z(m,n)* is the output of the linear low-pass filter, and *y(m,n)* is the enhanced image.

2.3. Wavelet fusion algorithm
This paper uses low-pass filter and high-pass filter to convolution filter the image. The image is decomposed into high frequency and low frequency through wavelet transform, and the fusion process is performed separately. Finally, this paper is inversely transformed to the image matrix [11]. Wavelet transform fusion is an orthogonal transform that analyzes the original image to form sub-images of low frequency LL, high frequency HL, low frequency HL, and high frequency HH. When performing a two-layer or higher-layer wavelet transform on an image, only the low-frequency subband LL is decomposed, as shown in figure 2.

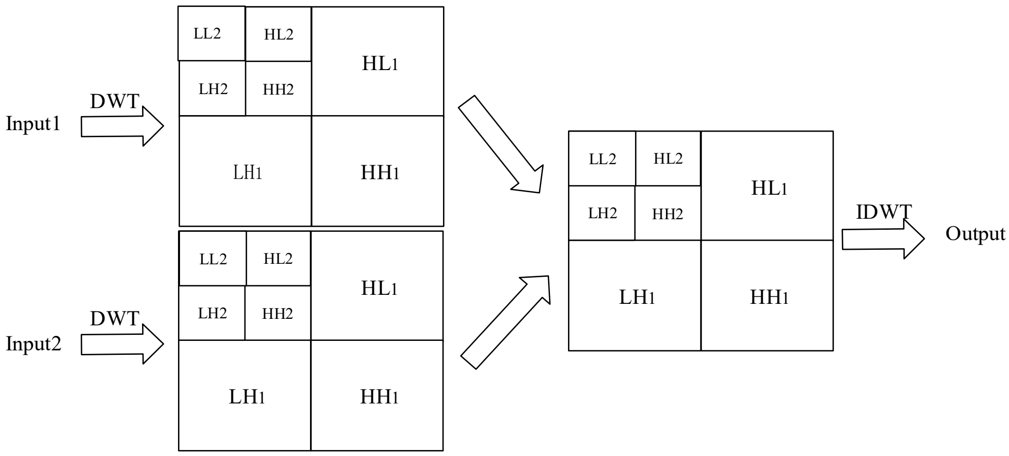

Figure 2. Decomposition, fusion of coefficients and image synthesizing.

In order to balance the relationship between contrast and saturation of underwater images, this paper uses smy4 wavelet to merge two images decomposed by three-level wavelet. This paper uses wavelet change image fusion method to improve the contrast of underwater images and avoid color distortion.

3. Experimental results and analysis
In order to test the enhancement effect of the algorithm, this paper selects different types of underwater images for the color cast, low contrast and fuzz problems of the original underwater image. According to the scene, it is divided into three categories: color_cast, under_exposure and fuzz, and each type takes two pictures for analysis. We compare the algorithm in this paper with the SSR algorithm and the white balance algorithm on underwater images. And we evaluate and analyze the experimental results from the subjective and the objective evaluation index.

3.1. Subjective evaluation of enhancement effect
The comparison of the enhancement effect of the original underwater image with problems is shown in figure 3 to figure 5.

IOP Conf. Series: Earth and Environmental Science **615** (2020) 012120 doi:10.1088/1755-1315/615/1/012120

(a)Original image (b)SSR algorithm (c)White balance (d)Our algorithm

Figure 3. Comparison of enhancement effects with color cast in the original image.

(a)Original image (b)SSR algorithm (c)White balance (d)Our algorithm

Figure 4. Comparison of the enhancement effect of the original image with low contrast problems.

(a)Original image (b)SSR algorithm (c)White balance (d)Our algorithm

Figure 5. Comparison of enhancement effects with fuzz in the original image.

After the SSR enhancement algorithm is used to process the original underwater image, the brightness of the image is greatly improved. The underwater image processed by the algorithm will have whitening and blurring, and there will be color distortion and high contrast. After the white balance enhancement algorithm is used to process the original underwater image, the algorithm effectively solves the color cast problem and improves the brightness and contrast of the image. However, the underwater image processed by the white balance enhancement algorithm has the problem of unclear details and texture, and the problem of excessive enhancement of image color. After the algorithm proposed in this paper is used to process the original underwater image with color cast. The details and texture of the underwater image are improved. The fuzz problem of the underwater image is improved. And the color cast, low contrast and fuzz issues.

3.2. Objective evaluation of enhancement effect

In order to more objectively verify the effect of the method in this paper, this paper adopts the non-reference quality evaluation method for underwater images Underwater Image Quality Measure (UIQM) [12] and Information Entropy. We compare our method with SSR algorithm and white balance algorithm for objective evaluation. This paper uses objective evaluation indexes to evaluate the effects of different types of images. And the experimental results are shown in table 1.

Table 1. Objective evaluation indexes of different algorithms.

Evaluation index	Picture name	Original image	SSR algorithm	White balance	Our algorithm
UIQM	color_cast1	0.2637	2.6738	3.5337	4.1528
	color_cast2	1.0759	3.4786	2.9637	4.7277
	under_exposure1	2.5010	3.7328	3.2548	4.1289
	under_exposure1	0.6448	1.5494	4.5091	4.8026
	fuzz1	2.2329	3.2654	3.1639	4.3112
	fuzz2	1.6276	3.4313	3.5014	4.7308
Information Entropy	color_cast1	7.5844	7.3099	7.4643	7.6389
	color_cast2	5.6564	5.6493	5.4458	7.3447
	under_exposure1	7.3034	6.9566	7.4456	7.8560
	under_exposure1	7.0028	6.4351	6.8961	7.4372
	fuzz1	6.9072	7.1722	6.9515	7.6226
	fuzz2	6.6763	7.1078	7.0201	7.6590

It can be seen from table 1 that the algorithm in this paper performs well in various quality evaluation indicators. The algorithm in this paper has a significant enhancement effect on underwater degraded images, and has a certain effect on the color cast, low contrast and fuzz problems of underwater images.

4. Conclusion

Aiming at the problems of the original underwater image, this paper uses the Retinex algorithm, gamma correction and sharpening correction algorithms to improve the problems existing in the underwater image. Finally, this paper uses wavelet fusion algorithm to make the processed underwater image closer to the real image in the natural scene. The experimental results show that the algorithm in this paper can effectively enhance the underwater degraded image, so that the visual effect and objective quality of the image are significantly improved. The algorithm in this paper has a certain corrective effect on the problems of the three underwater original images. And the algorithm in this paper solves the problems of color deviation, low contrast and blurring of underwater images to some extent.

References

[1] Rodrigues, P. M., Cruz, N. A., & Pinto, A. M. (2018). Altitude control of an underwater vehicle based on computer vision. In OCEANS 2018 MTS/IEEE Charleston.
[2] Wang, Y., Song, W., Fortino, G., Qi, L., Zhang, W., & Liotta, A. (2019). An Experimental-Based Review of Image Enhancement and Image Restoration Methods for Underwater Imaging. IEEE Access, 7, 140233–140251.

[3] Zhang, W., Li, G., & Ying, Z. (2017). A new underwater image enhancing method via color correction and illumination adjustment. In 2017 IEEE Visual Communications and Image Processing (VCIP) (pp. 1–4).
[4] Subah, S. S., Islam, M. A., & Islam, M. M. (2019). Underwater Image Enhancement Based on Fusion Technique via Color Correction and Illumination Adjustment. In 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT) (Vol. 2019, pp. 1–5).
[5] Yang, Y., & Xu, X. (2020). A Underwater Image Enhanced Algorithm combined MSR and Channel Energy. In 2020 22nd International Conference on Advanced Communication Technology (ICACT).
[6] Sanila, K. H., Balakrishnan, A. A., & Supriya, M. H. (2019). Underwater Image Enhancement Using White Balance, USM and CLHE. In 2019 International Symposium on Ocean Technology (SYMPOL).
[7] Tang, C., Lukas, U. F. von, Vahl, M., Wang, S., Wang, Y., & Tan, M. (2019). Efficient underwater image and video enhancement based on Retinex. Signal, Image and Video Processing, 13(5), 1011–1018.
[8] Zhang, S., Wang, T., Dong, J., & Yu, H. (2017). Underwater image enhancement via extended multi-scale Retinex. Neurocomputing, 245, 1–9.
[9] Mohan, S., & Simon, P. (2020). Underwater Image Enhancement based on Histogram Manipulation and Multiscale Fusion. Procedia Computer Science, 171, 941–950.
[10] Ancuti, C. O., Ancuti, C., Vleeschouwer, C. D., & Bekaert, P. (2018). Color Balance and Fusion for Underwater Image Enhancement. IEEE Transactions on Image Processing, 27(1), 379–393.
[11] Wang, Y., Ding, X., Wang, R., Zhang, J., & Fu, X. (2017). Fusion-based underwater image enhancement by wavelet decomposition. In 2017 IEEE International Conference on Industrial Technology (ICIT) (pp. 1013–1018).
[12] Panetta, K., Gao, C., & Agaian, S. (2016). Human-Visual-System-Inspired Underwater Image Quality Measures. IEEE Journal of Oceanic Engineering, 41(3), 541–551.