Underwater Image Enhancement Method Based On Color Correction and Dark Channel Prior

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Abstract. Concerning to the problem in the distortion of color and the low contrast of underwater image, the image enhancement method in the underwater environment based on color correction and dark channel prior was proposed. When dealing with the color bias problem, the blue channel standard ratio is firstly calculated based on the blue channel, and the red and green channels of the underwater image are compensated to remove the blue and green background colors of the underwater image. In light of the problem in the low contrast of image in underwater environment, the dark channel prior (DCP) method based on the super pixel was used to enhance the corrected underwater image. Finally, the underwater object detection dataset images are tested, and the algorithm proposed in terms of the quality is made the comparison with six advanced image enhancement method in underwater environment. The experimental results show that the proposed algorithm earned the highest score in underwater quality evaluation index (UIQM) compared with the above algorithm.

Keywords: Image Enhancement, White Balance, Color Channel Compensation, Color Correction, the Dark Channel Prior

1. Introduction
Due to the lack of illumination and the scattering of light by underwater particles, the underwater image proves the existence of the problem of color bias and low contrast compared with the ordinary images. For the purpose of improving the image quality, He Kaiming [1] proposed an image defogging (DCP) method using a dark channel prior in 2009, which was adopted to estimate the intensity of other channels of the image through the darkest channel, and to carry out an effective and simple single image preprocessing and defogging. Due to extensive research on image defogging algorithm, more and more researchers began to enhance underwater images by the principle of defogging algorithm. Based on DCP algorithm, Paulodrewsjr [2] proposed UDCP algorithm using blue-green channels of underwater images as information sources, which improved the contrast of underwater images. Rhummel [3] proposed a kind of image enhancement using histogram. Iqbal [4] et al. Put forward in 2010 for enhancement of image quality by adopting an color correction method unsupervised. Swei et al. [5] proposed a scene depth estimation model for underwater images based on a prior of underwater optical attenuation (ULAP), and estimated the scene depth of underwater images.
by using supervised linear regression on model coefficients. Pengy [6] enhanced and restored the underwater image based on the depth estimation method of the underwater scene and image blur and light absorption by using the image formation model (IFM). According to the concept of image fusion, Codrutao-Ancuti [7] adopted the two color compensation and white balance methods to obtain two images, and the multi-scale fusion method was adopted to improve the precision of image restoration, and it is called UWB [8] method.

The above algorithms have poor adaptability in color correction, which will cause the underwater image to be redder and the image will be too dark when the comparison for the image in underwater environment is improved. Aiming at above two problems of current underwater image enhancement algorithms, an image enhancement method in underwater environment is put forward based on color correction and dark channel prior. The method consists of two steps. In the first step, the channel compensation method of the blue channel standard ratio improved UWB algorithm is adopted to correct image color bias. In the next step, based on the dark channel dehazing algorithm, local superpixel segmentation is used to improve the calculation method of its transmittance, and in this process, three channels of simple weighted average backscattered light are used for evaluation of the transmission image to enhance the image contrast.

2. Principle of Algorithm

2.1 Underwater Image Color Correction Based on UWB

Ancuti et al. [8] propose the underwater image white balance (UWB) method in 2018 to deal with the color distortion of images in underwater environment. The algorithm compensated the red channel of the image based on the mean difference between red and green channels, and selectively compensated the blue channel when the blue channel attenuates strongly [9].

This paper takes the blue channel as the standard and the UWB algorithm is further improved to obtain the following equation:

$$I_n'(A) = I_r(A) + \frac{I_b(A)}{I_r(A)} \cdot \frac{T_r}{T_b} \left( T_b - T_r \right) \cdot (1 - I_r(A)) \cdot I_b(A)$$  

(1)

$$I_b'(A) = I_g(A) + \frac{I_b(A)}{I_g(A)} \cdot \frac{T_g}{T_b} \left( T_b - T_g \right) \cdot (1 - I_g(A)) \cdot I_b(A)$$  

(2)

Where, $I_b(A) / I_r(A)$ and $I_b(A) / I_g(A)$ are the improved correction coefficient based on UWB algorithm proposed in this chapter. $I_n'(A), I_g'(A)$ refers to the value of red and green channels at points of underwater images by means of color compensation with the improved method. When there is a big difference between the blue channel and the red channel at a pixel point, we fully increase the value of the red channel by the inner part of the correction coefficient $I_b(A) / I_r(A)$ and limit its size by the mean value of the blue channel and the mean value of the red channel of the image $T_r / T_b$, so that there is not much compensation.
2.2 Underwater Image Contrast Enhancement Based On the Dark Channel Prior

The low contrast of underwater image is similar to fuzzy image obtained on foggy days, so the color-corrected underwater image can be enhanced by using the commonly used haze removal framework [1].

In this paper, the underwater image IP with color correction is segmented to super pixel blocks. The backscattered light and image of transmission of original image after super pixel segmentation are estimated. An algorithm based on fuzzy simple linear iterative clustering (fuzzySLIC) [10] was used to decompose the image into N superpixels. Supposing that $M_i$ is the ith superpixel. According to DCP, the minimum channel value of the dark image of the superpixel segmentation image can be acquired as follows (3):

$$I_{p_{\text{dark}}}^c(i) = \min \left( \min I_p^c(z) \right)$$

(3)

Among which, $I_{p_{\text{dark}}}^c(i)$ denotes the ith dark pixel corresponding to the sixth superpixel, and $c$ is the channel of $r, g, b$ and $z \in M_i$. The transmission image is estimated as follows by using the dark image based on super-pixel DCP:

$$t_{sp}(i) = 1 - \omega \frac{I_{p_{\text{dark}}}^c(i)}{A_{sp}^c}$$

(4)

In the above-mentioned equation, $t_{sp}(i)$ is the transmittance value of the current medium, $A_{sp}^c$ denotes the backscattered light of the dark pixel. Besides, $\omega$ refers to the weight. In order to make the image with enhanced contrast closer to the image in the real environment, three color channel formulas of the average backscattered light with determined weights are proposed in this paper, as shown in Equation (5):

$$\sigma = \min \left( \left( A_{sp}^r + A_{sp}^g + A_{sp}^b \right)/3, A_{sp}^b \right)$$

(5)

According to the above ideas, the overall image recovery equation of the improved DCP algorithm is shown in the equation (6) as follows:

$$J_c(x) = \frac{I_p^c(x) - A_{sp}^c}{\max \left( t_{sp}(x), t(0) \right)} + A_{sp}^c$$

(6)

Among which, $J_c(x)$ signifies the final result image obtained through the algorithm in this paper, $t(0)$ is a small constant threshold, which $t(0)$ is set to 0.1 in this paper.

3. Experimental Results

With the purpose to prove the effectiveness of this algorithm, it is compared with several traditional algorithms such as DCP algorithms[1], HE algorithm[3], UDCP algorithm[2], UCM algorithm[4], ULAP algorithm[5] and IBLA algorithm[6], which have better image enhancement effect. In the experiment, the original underwater image used for underwater Marine object detection and image segmentation is used for testing. Qualitative and quantitative comparisons were made during the experiment. The six traditional algorithms and the algorithm in this paper are respectively used for experimental comparison. Five images of different scenes were selected for display, as shown in Figure 1 below:
Figure. 1 Comparison results of various methods

As shown in Figure 1, the method presented in the paper can effectively restore image details, enhance image contrast and balance color bias without the problem of too bright color.

In order to carry out objective quantitative comparison, the average value of the underwater image quality evaluation indexes obtained after 100 underwater images processed was calculated during the experiment. The comparison results are shown in Table 1 below. We represented the best results in bold with italics.

| Algorithm | DCP | UDCP | HE | UCM | ULAP | IBLA | Ours |
|-----------|-----|------|----|-----|------|------|------|
| UICM      | 4.7557 | 4.5033 | 10.0308 | 3.3776 | 3.4676 | 3.7523 | 3.771 |
| UISM      | 5.1677 | 5.4578 | 6.6644 | 6.0534 | 5.1177 | 5.4140 | 6.4364 |
| UIConM    | 0.1843 | 0.1423 | 0.2441 | 0.2652 | 0.2103 | 0.2910 | 0.3302 |
| UIQM      | 2.3189 | 2.2475 | 3.1236 | 2.8309 | 2.3608 | 2.7451 | 3.1878 |

As shown in Table 1, both UISM and UIConM of the algorithm in this paper have relatively high scores, which indicates that the algorithm proposed can improve the contrast and image clarity of underwater images in an effective manner. In the comprehensive index UIQM, the algorithm in this paper gets the highest score, indicating that the algorithm in this paper is ahead of the above algorithms in the comprehensive improvement of underwater image quality.

4. Conclusion
Concerning the two issues in color distortion and the low contrast of underwater image, the image enhancement method in underwater environment is put forward based on color correction and dark channel prior. The ratio of blue channel to the standard channel is used as the weight factor to compensate the green channel and the red channel and to remove the blue-green background color of the image. Concerning the underwater image corrected, a superpixel-based dark channel prior algorithm is adopted for restoration of the underwater image. During this process, we utilized an adaptive weighting factor based on the mean value of backscattered light for estimation of the transmission image. Finally, we conducted an experiment with the use of real Marine image collected from near shallow sea as the data set. The experimental results show that the proposed algorithm is superior to other enhancement algorithms in the comprehensive effect of color correction and contrast enhancement, which enjoys the better visual effect.

Founds project: Collaborative monitoring of nuclear dispersal of pollution in exposed ocean, situation analysis and the application demonstration (18zg6103); Key technology on intelligent identification and sorting of radioactive Objects (18zs2143); Research on key technologies of radioactivity detection in the underwater area and prediction of contamination level (19zs2148)

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