Research on underwater image enhancement algorithm based on improved DCP

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Abstract. All for underwater images, there are some drawbacks, such as low definition, serious color bias, dark brightness, etc. On the basis of in-depth analysis of common image enhancement algorithms, This paper uses the improved dark channel priority algorithm to enhance the underwater image, Improving the contrast of underwater images and color correction of underwater images. Color correction is added based on dark channel prior algorithm; Make the image look more even, higher contrast, more acceptable. The improved algorithm model has a higher transfer rate; PSNR is more balanced and has better contrast to meet the requirements of underwater image observation.

Keywords: Underwater image, contrast ratio, color correction, transmit rate.

1. Introduction

With the increasing consumption of land resources, the development of marine resources and the increasing frequency of underwater operations, the rapid development of underwater target detection and recognition is promoted. Underwater target recognition technology is the key research object in underwater detection, and has broad application prospects. Although underwater target recognition technology based on acoustic vision plays a leading role, optical vision plays an irreplaceable role in close underwater operation because it can give people the most intuitive and rich visual perception [1][2].

In reference [3], the optimized msrcr algorithm is used to estimate the image illumination and eliminate the influence on the image color. At the same time, the improved yolov3 target detection algorithm is used to deepen the network depth, enhance the feature propagation and improve the detection accuracy of sea cucumber. Reference [4] proposed a method to improve the underwater image contrast and the number of image feature matching. The histogram algorithm is used to enhance the underwater image, and the image with uniform brightness distribution and improved contrast is obtained. The number of feature matching is significantly increased, and the result of feature point extraction is consistent. According to the serious degradation of underwater image in reference [5], firstly, an enhancement algorithm based on dark channel prior and color correction is proposed, and two control parameters are introduced to estimate the wavelength, and color correction is used to correct the color deviation, so as to improve the underwater image quality and visual effect.
2. The influence of underwater environment on image quality
The water quality in the natural environment has a lot of dissolved matter and particulate matter. The light propagation in the water will be affected by the water body and suspended matter. On the one hand, the absorption effect of water will be attenuated; on the other hand, the suspended matter and water body will diverge and absorb, changing the direction of light propagation and reducing the amount of light [6].

Firstly, the water body will scatter the light and change the direction of light propagation; Secondly, water will absorb light and reduce the amount of light. According to the scattering and absorption effect, the attenuation effect of underwater light propagation is caused. According to Lambert-Beer empirical law, the attenuation model of underwater light is obtained:

\[ L = L_0 e^{-cr} \]

Where \( L \) and \( L_0 \) represent the light intensity and initial light intensity after \( r \) distance propagation in water respectively, and \( c \) represents the attenuation coefficient of water body.

![Figure 1. Underwater image formation process.](image)

The scattering function of light under water is calculated as follows:

\[ L(x, \lambda) = L_0(x, \lambda) e^{-a(\lambda)r(x)} \]

\( \lambda \) Represents the wavelength of light, \( a(\lambda) \) Represents the total scattering coefficient of a water body, \( r(x) \) It's the distance light travels in water, \( L_0(x, \lambda) \) Is the initial light intensity, \( L(x, \lambda) \) Is the propagation distance in water, \( r(x) \) The intensity of light.

The scattering function of light under water is calculated as follows:

\[ L(x, \lambda) = L_0(x, \lambda) e^{-b(\lambda)r(x)} \]
Absorption coefficient of water body. Based on the above optical properties, the calculation formula of light attenuation in water body can be expressed:

\[ L(x, \lambda) = L_0(x, \lambda) e^{-c(\lambda)r(x)} \]

\( c(\lambda) \) is the total attenuation coefficient. From the total scattering coefficient \( a(\lambda) \) and the total absorption coefficient \( b(\lambda) \) decision.

### 3. Description of dark channel prior algorithm

Dark channel prior algorithm is a simple and efficient image defogging algorithm, which focuses on the statistics of non-fogging image, and can directly evaluate the projection information of fog and light from the dark pixels in the image [7]. The value of one of the three channels of each pixel in the image is very low. The image composed of the darkest channel value is called dark channel image.

Firstly, the DCP algorithm is used to construct the image degradation model. The definition of dark channel is as follows:

\[ J^\text{dark}(x) = \min_{j \in \Omega(x)} \left( \min_{c=[r,g,b]} J^c(y) \right) \]

among, \( J^\text{dark}(x) \) Represents a dark channel image, \( x \) Represents the pixel coordinate vector in the image \( x = (x, y)^T \), \( J^c(y) \) Represents the image of each channel in the original channel, \( c \) Three channels representing RGB image, \( \Omega(x) \) Represents a window centered on \( x \).

![Figure 2. Original picture.](image)

![Figure 3. Dark channel prior processing results.](image)

The image is a clear outdoor image, the corresponding dark channel image and the dark channel image calculated by blocks. From the image, we can see that most of the pixels in the dark channel image have very low brightness values, and a few areas with high brightness are caused by the background light or the natural light reflected from the lake.

### 4. Improved dark channel prior theory

Because the dark channel prior algorithm can not accurately estimate the transmission image of three color channels of underwater image, which affects the quality of restored image, it is necessary to improve the prior algorithm for underwater image processing. By combining colors, the saturation image improves the estimation of the background light, and then uses the dark channel prior to get the transmission map of the red channel, introduces the control parameter to estimate the attenuation coefficient ratio between different color channels, and estimates the transmission map of the blue and green channels according to the estimated attenuation coefficient ratio, so as to improve the processing effect of the dark channel prior to restore the underwater image [8].
In order to restore the real scene of the image, it is necessary to estimate the background light of the image first. However, the overall atomization effect of the underwater image is serious, and the overall brightness of the dark channel of the image is high. This method is easy to make mistakes. In fact, the real background light is in the farthest area of the image, as shown in the figure.

**Figure 4.** Background light estimation for underwater image.

Dark channel prior algorithm is used to estimate the background light of underwater image. The red box is the farthest part of the image, which is the location of the real background light. Although the yellow mark is the brightest, it is the estimated location of the background light.

For the high brightness area of underwater image, the brightness of the three color channels is more balanced; In the background area of underwater image, the brightness of the three color channels is very uneven, generally blue or green, which is the definition of color saturation:

$$\text{satuation}_{g} = \max (R, G, B) - \min (R, G, B)$$

Among $\max (R, G, B)$ and $\min (R, G, B)$ represents the maximum and minimum value of RGB channel of a pixel respectively. The color saturation can be used in the dark channel image to reduce the adverse effect of high brightness on the background light.

### 4.1 Underwater image scene restoration

After getting the background light of underwater image and the transmission image of each color channel, we can restore the scene brightness of the underwater image. The visual effect of the restored underwater image is significantly enhanced, which effectively improves the visibility and clarity of the underwater image, improves the contrast of the image, and highlights the contour and edge of the object.

**Figure 5.** Underwater image restoration.
4.2. Color correction
In this paper, the attenuation coefficient is estimated by introducing two parameters, so there are errors, so color correction is needed to balance the color of the restored image and improve the overall visual effect of the image.

![Color channel refined transmission graph.](image)

The traditional algorithm calculates the maximum value of each color channel, and takes the color corresponding to the maximum value as the main channel, and the other two color channels as the secondary channel. In this paper, the average value of each color channel is calculated to determine the main color channel of the image, and then the brightness of the other two color channels is increased to balance the image color. The formula is as follows:

\[
R_{\text{avg}} = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} I_r(i, j)
\]

\[
G_{\text{avg}} = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} I_g(i, j)
\]

\[
B_{\text{avg}} = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} I_b(i, j)
\]

Where $MN$ is the number of pixels of a single color channel of the image. After calculating the average value of each channel, the maximum average value is used as the corresponding color as the main channel, and the other two channels are magnified. The magnification factor is as follows:

\[
gain_A = \frac{\max(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})}{\min(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})}
\]

\[
gain_B = \frac{\max(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})}{\text{med}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})}
\]

Finally, the two secondary channels are magnified to balance the color of the image, such as the formula:

\[
\tilde{I}_{\text{min}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) = \text{gain}_A \times I_{\text{min}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})
\]

\[
\tilde{I}_{\text{med}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) = \text{gain}_B \times I_{\text{med}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}})
\]
Where \( I_{\text{min}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) \) is the color channel with the smallest mean value, \( I_{\text{med}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) \) is the color channel with the middle mean value, and \( \tilde{I}_{\text{min}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) \) and \( \tilde{I}_{\text{med}}(R_{\text{avg}}, G_{\text{avg}}, B_{\text{avg}}) \) are the corresponding color channel values after magnification.

![Figure 7. Image algorithm in this paper.](image)

5. Conclusions

Peak signal-to-noise ratio (PSNR) is a commonly used evaluation index to evaluate the effect of image processing algorithm. It is the ratio of image signal to image noise power spectrum. The higher the signal-to-noise ratio, the smaller the noise in the signal, the better the image effect. As can be seen from the table below, the PSNR value of the improved dark channel prior algorithm is 16.20, compared with the original PSNR value of 13.88, the image effect is better and clearer.

| Algorithm                      | dark channel prior theory | Improved dark channel prior theory |
|--------------------------------|---------------------------|-----------------------------------|
| PSNR                           | 13.88                     | 16.20                             |

Table 1. Comparison of different algorithms.

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