Research on underwater image enhancement algorithm

Abstract: In recent years, with the continuous expansion of human activity areas, the Marine pollution caused by human activities has become increasingly serious, and the large influx of agricultural emissions and household garbage needs to rely on underwater equipment to clean up. However, to identify garbage from the complex underwater environment, it is necessary to study the underwater image enhancement algorithm. Therefore, this paper takes underwater plastic floaters as the research object, starts with the optical imaging model of underwater images, analyzes the process and mechanism of underwater optical imaging, and its impact on image quality, so as to better understand the causes of image degradation. Based on white balance algorithm, histogram equalization algorithm, bilateral filter algorithm and gamma correction method, the underwater image recognition image is improved. The principle of these methods to enhance underwater image is analyzed and applied to further improve the effect of underwater image enhancement.

Keyword: Identify;Imaging model;Algorithm;Underwater image enhancement

1 INTRODUCTION

With the continuous development of science and technology, the exploitation of Marine resources has gradually attracted the attention of many countries and researchers. About 70 percent of the earth's surface is covered by the ocean. For human survival and development, the energy and materials contained in the ocean are essential for the high-quality and rapid development of mankind. However, the development of society has brought about the impact of human industrialization on the waters, including oceans, rivers, lakes, etc., which have successively become the home of garbage and plastics, so the comprehensive utilization of water resources has become one of the priorities of development, and only reasonable development and protection can achieve sustainable development[2].Compared with the land environment, underwater environment is much more complex, which is not only affected by light, but also by floating objects, noise, etc. Acquiring target feature information from such complex environment and conducting classification and recognition is the main research direction in the field of underwater target classification[2]，Whether the underwater equipment can process the video image clearly is the key step to realize further research. Clear underwater images can provide more detail and information to help identify the shape, size, structure and features of the target. Through image sharpening technology, the blur and noise of underwater environment can be reduced, making the target more prominent and easy to recognize. This is of great significance for underwater exploration, Marine scientific research, underwater search and rescue and military applications. In underwater operations, clear underwater images can improve work efficiency, reduce misjudgments and improve the accuracy of target recognition. Therefore, underwater image sharpening technology plays a crucial role in underwater target recognition.

To solve the problem of low image quality and poor definition of underwater images, scholars at home and abroad have done a lot of research. Tang [3] et al. proposed an underwater image enhancement method that applied guided filtering to algorithm improvement to improve image color saturation and richness. Bazeille[4] et al. designed a novel preprocessing filter that can reduce underwater disturbance and improve image quality. Galdran [5] et al. solved the problems of underwater visibility loss and color loss based on red channel priors. Li[6] et al. established a mixing framework for underwater image enhancement, which improved the problems of underwater image in terms of color correction, fog removal, detail clarification, etc. Liu[7] et al. proposed a method based on image formation model and neural network to embed modified underwater images into grid design. Rao[8]et al. improved the histogram equalization algorithm by optimizing particle swarm optimization, effectively improving the clarity of underwater images.

Based on the optical imaging model of underwater images, this paper will study the phenomena of light and water in the underwater imaging system, and analyze the enhancement of underwater images by white balance algorithm, histogram equalization algorithm, bilateral filtering algorithm and gamma correction method.

2 OPTICAL IMAGING MODELFORUNDERWATERIMAGES

An underwater optical model is a model that describes the propagation and imaging of light under water. In the underwater environment, light will be affected by refraction, scattering and absorption, etc. It is necessary to consider these factors, and describe underwater optical imaging from different levels, predict the imaging effect under different water quality conditions, and help design underwater imaging systems and optimize imaging quality. Commonly used underwater imaging models include Snell's Law, which describes the law of light refraction between two media. According to Snell's law, light refraction occurs when passing through the interface of two media, and the refraction Angle depends on the refractive index and incidence Angle of the two media. The scattering model describes the process by which light is scattered when it encounters particles or other inhomogeneity in water. Scattering will cause the propagation direction of light to change and affect the image quality. The light propagation model describes the entire process of light propagation and imaging under water. These models can be modeled and simulated based on physical optics principles and mathematical methods to help understand the complexity of underwater optical imaging. Also representative optical models of underwater images include Lambert-Beer absorption model and Jaffe McGlamer model.

2.1 Lambert-Beer absorption model

The Lambert-Beer absorption model [9] is a basic model to describe the propagation and absorption of light in a transparent medium. The key point is that the absorption of light in a transparent medium is proportional to the concentration of the substance, and is exponentially related to the increase of the optical path. The exponential attenuation of light intensity is revealed as the distance it travels in the medium increases. The model formula is shown below.

$$A = log_{10}(\frac{I_0}{I}) = Klc \tag{1}$$

Formula 1, A- Absorbance;

I_0- Incident light intensity, I- The intensity of the emerging light;

K- Molar absorption coefficient;

l- The distance of transmitted light;

c- The concentration of light-absorbing substances , mol/L;

Kc the attenuation coefficient, is related to the properties of the absorbing material and the wavelength λ of the incident light.

2.2Jaffe McGlamer model

In the development of underwater optical imaging models, the most representative one is the relatively clear description of the imaging process. The Jaffe McGlamer model [10] proposed by Jaffe et al at the end of the 20th century [10], as shown in Figure 1, in the absence of artificial light, the light entering the camera mainly consists of three components.

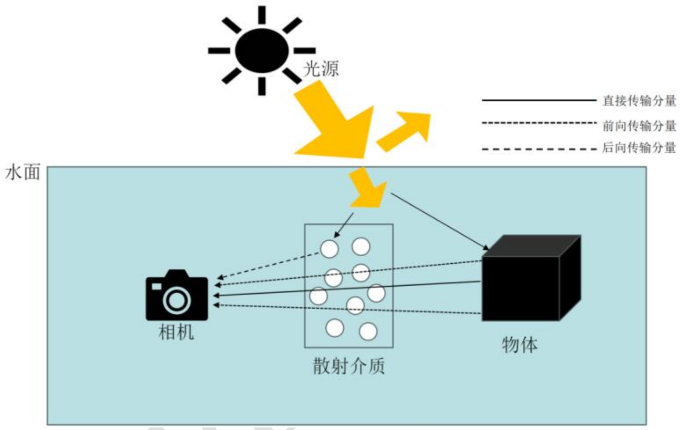


Fig 1. Underwater optical imaging

(1)Direct transmission componentE_D,The amount of light that comes from a light source directly to an object and then reflects off the camera. In each image,E_D It can be expressed as:

$$E_D(x) = J(x)\tau(x) \tag{2}$$

Formula 2,$J(x)$- The directly reflected part of the target object;

$\tau(x)$- Transmissivity.

(2)Forward transmission component E_F ,In underwater environments, floating particles can cause scattering of incident light. This causes the reflected light from the target object to enter the camera at a small angle after passing through the suspended object, thereby blurring the image locally. This forward scattering causes the light to randomly shift before it enters the lens. It is found that its effect can be approximated by the convolution of direct attenuation with the point diffusion function, which depends on the distance of the object from the imaging plane.

(3)The backscattered componentE_B,Backscattering is the phenomenon that when light is scattered with matter particles or molecules, part of the light changes the direction of propagation and propagates in the opposite direction of the incident light, which is in contrast to forward scattering (forward scattering). In optical experiments, backscattering can be used to study the internal structure and composition of media.

3 Underwater image enhancement algorithm

Underwater image enhancement algorithm is a technology specially used to improve the quality of the underwater images. Due to the particularity of underwater environment, such as light attenuation, scattering and color absorption of water, there are often problems such as color distortion, low contrast and blurred details in underwater images. The aim of underwater image enhancement algorithm is to solve these problems, make the image closer to the real scene, and make the subsequent image analysis and processing easier.

The research approaches of underwater image enhancement algorithms mainly include traditional image enhancement techniques, methods based on color constancy theory and methods based on channel first (DCP) algorithm and its improved algorithm.

In this section, white balance algorithm, histogram equalization algorithm, bilateral filtering algorithm, and gamma correction method are analyzed to verify their improvement of underwater image quality.

3.1 White balance algorithm

White balance is a way to restore the color of an object from the color it appears under different light sources to the natural color of the object, in order to reduce color bias or colorless bias. Most of the underwater plastic waste is mainly white, and in the turbidity waters with more impurities, the white balance algorithm can make it revert to white. Common white balance algorithms include the original grayscale world algorithm and the perfect reflection algorithm. The Grayscale world algorithm assumes that the average reflection of all physical surfaces in the scene is achromatic (gray). As shown in Formula 3, the average color of the entire image is taken as the illumination color of the image. The algorithm has the advantages of strong adaptability to general images and relatively simple, so it is widely used. However, it is not suitable for scenes with relatively single colors in the image, and the underwater environment generally does not have rich and changeable colors, and the underwater scene studied in this paper has a standard light source provided by the underwater robot, so the perfect reflection algorithm is chosen.

$$\mathrm{G}_{\mathrm{ray}} = \frac{\overline{\mathrm{R}}+\overline{\mathrm{G}}+\overline{\mathrm{B}}}{3} \tag{3}$$

The perfect reflection algorithm is one of the most common algorithms of white balance. It assumes that the brightest white point in the image world is a mirror, which can perfectly reflect light [11]. It is a method to properly adjust the value of the three channels based on the white point (standard light source), so as to achieve the white balance effect. The difference between the mean and the maximum value of the channel determines the intensity of the channel adjustment. The specific implementation process is as follows: firstly,calculate the maximum gray values of the input image R(red), G(green) and B(blue) channels respectively, R_{max} , G_{max} and B_{max} ; Secondly, the sum of the three-channel values is used to determine the lower limit T of the brightest interval of the image. Then, the three-channel values of the image and the three-channel mean values of the points greater than T are calculated: $\bar{R}, \bar{G}, \bar{B}$.Then the gain coefficient of the three channels is calculated, that is, the maximum value of the single channel divided by the average value of the single channel bright area. Finally, according to the gain coefficient, each channel of each pixel of the image is processed, and the quantization is guaranteed to be in the interval of [0,255].

The expression for calculating the gain coefficient of each channel of the image is as follows:

$$\begin{cases} \mathrm{gain_R} = \mathrm{MaxVal}/\overline{\mathrm{R}} \\ \mathrm{gain_G} = \mathrm{MaxVal}/\overline{\mathrm{G}} \\ \mathrm{gain_B} = \mathrm{MaxVal}/\overline{\mathrm{B}} \end{cases} \tag{4}$$

Where, MaxVal is the maximum value of R,G, and B in all pixels, $\bar{R}$,$\bar{G}$,and$\bar{B}$are the mean values of pixels in each channel under the product of the R+G+B component of pixels and the ratio greater than the number of pixels in the image and the definition [12].

The last step is calculated and corrected. The formula is as follows:

$$\begin{cases} \mathrm{R}^* = \mathrm{gain}_{\mathrm{R}} * \mathrm{R} \\ \mathrm{G}^* = \mathrm{gain}_{\mathrm{G}} * \mathrm{G} \\ \mathrm{B}^* = \mathrm{gain}_{\mathrm{B}} * \mathrm{B} \end{cases} \tag{5}$$

The effect of using the perfect reflection algorithm for underwater image processing is shown in the following figure, the left picture is the original image, and the right picture is the image processed by the perfect reflection algorithm. It can be seen that the white plastic can be restored to natural color.

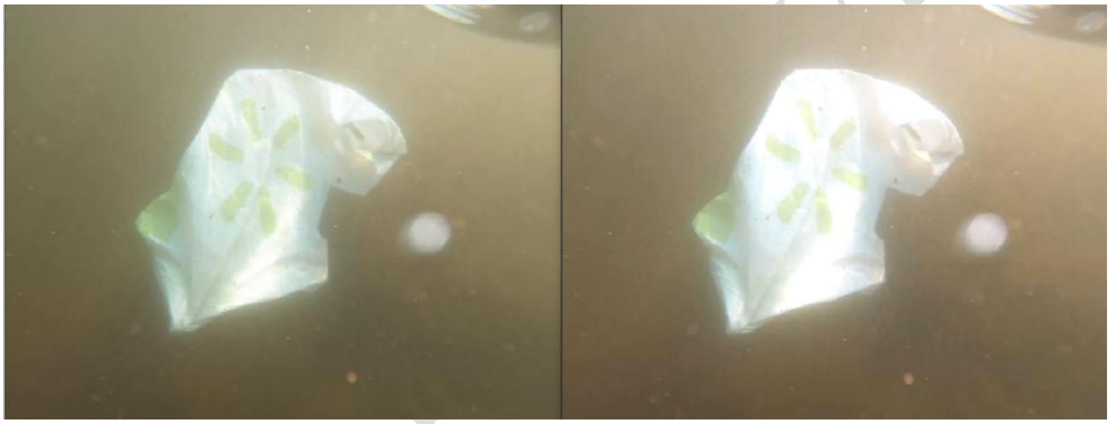


Fig 2. Comparison of raw and white balanced images

3.2 Histogram equalization algorithm

The image processed by the perfect reflection algorithm still has the problem of low contrast and noise. In this study, the adaptive histogram equalization algorithm is used to make the image brighter and reduce the noise. The histogram of the image is used to represent the brightness distribution of the image, which can reflect the frequency or number of pixels that make up the gray level of the image. Most image histograms are one-dimensional, and the horizontal axis represents the gray level, and the vertical axis represents the frequency of the gray level in the image. Histogram equalization (HE)[13] is to transform the gray level histogram of the original image into a histogram with uniform distribution through nonlinear transformation, so as to improve the contrast of the entire image and make the image clear.

Assuming that the total number of pixels in the underwater image is L, the distribution range of its gray level is [0,L-1], and r is the gray level of the image to be processed. When r=0, the gray level is black; when r=L-1, the gray level is white; N is the total number of pixels in the image; r_k is the gray level of k. $n_k$is the number of pixels in the image whose gray value is r_k, then P(r_k) is the probability of occurrence in the image at the gray level ofr_k, which can be expressed as:

$$P(r_k) = \frac{n_k}{N}, k \in [0, L-1] \tag{6}$$

For an image with discrete gray levels, the nonlinear transformation mapping function s_k can be expressed as:

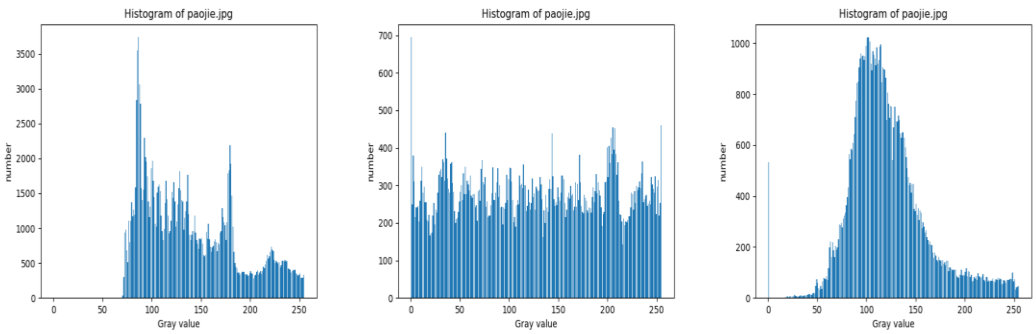
$$s_k = T(r_k) = \sum_{i=0}^{k} p_r(r_i) = \sum_{i=0}^{k} \frac{n_i}{n}, \quad k \in [0, L-1] \tag{7}$$

For images with continuous gray level, the nonlinear transformation mapping function s_k is expressed as:

$$s_k = T(r) = \int_0^1 P_r(r) d_r, \quad r \in [0,1] \tag{8}$$

However, when there are parts in the image that are obviously brighter or darker than other areas of the image, the effect of histogram equalization is not good, especially for images with high contrast, histogram equalization may lead to excessive enhancement of some details in the image. Therefore, researchers propose an Adaptive Histogram Equalization (AHE)[14], which improves histogram equalization technology to a certain extent, mainly by dividing images to be processed into several local regions. Then, histogram equalization is applied to each region, which can enhance the contrast of each region more flexibly. However, the adaptive histogram equalization algorithm simply superposes the equalization results of each region, amplifies the noise in the image, and there may be obvious edges at the junctions of different small regions, resulting in poor continuity of the image.

In response to the above problems, Contrast Limited Adaptive Histogram Equalization (CLAHE) [15] is proposed to limit the increase of contrast based on AHE algorithm. It can enhance the local contrast of the image, while preventing excessive enhancement of noise. In this method, the image is divided into several overlapping local areas, and the pixels in each local area are processed by histogram equalization to increase the local contrast. In the process of equalization, a threshold is set. When the gray level of a certain area in the image histogram exceeds the threshold, it is cut, and then the parts exceeding the threshold are evenly allocated to each gray level. This will make the result of the mapping function flatter. Below is the underwater image processed by different histogram equalization algorithms and its corresponding histogram. The original image shown in Figure 3-(a) is not clear enough due to light attenuation and dispersion in the underwater environment, resulting in slight chromatic aberration and uneven distribution of the corresponding histogram; However, after histogram equalization processing, the color deviation problem of Figure 3-(b) is alleviated, and the image contrast is significantly improved. However, this processing step may introduce a lot of noise, resulting in a large color difference in the background color of the image. It can be seen from the corresponding histogram that the overall gray distribution of the image is more uniform; The effect of noise is suppressed and image details are enhanced. In Figure 3-(c), adaptive histogram equalization with limited contrast is adopted, which applies histogram equalization and limits contrast in a local area. In contrast Figure 3-(b), noise is suppressed while contrast is improved, and the pattern on the image is more obvious. The detailed information is enhanced and the contrast between the main part of the image and the background is increased. The corresponding histogram is more uniform than the original image, and the gray level of the image is better distributed over the whole dynamic range.



(a) Original image (b)HE processing result(c) CLAHE processing result

Fig3.Image and Corresponding Histogram

3.3 Bilateral filtering algorithm

Image denoising processing mainly includes frequency domain denoising and spatial domain denoising [16]. Frequency domain denoising is noise processing by converting an image into the frequency domain (for example, using the Fourier transform). The main idea is to filter out noise components in the frequency domain, and the commonly used frequency domain denoising method is to use low-pass filter. Spatial domain denoising is a method to deal with image pixels directly, that is, to deal with noise in the original representation of the image. The method directly considers the spatial position of the image, and can be linear filtering and nonlinear filtering. The classical linear filtering methods include mean filtering and Gaussian filtering, and the nonlinear filtering methods include median filtering and bilateral filtering. The linear filter is a weighted sum of each pixel in the image, that is, the output value of each pixel is the weighted sum of some input pixels, and the advantage of the linear filter is that it is easy to construct. But when the noise is shot noise rather than Gaussian noise, the image is blurred with a Gaussian filter, and the noise is simply converted into softer but still visible shot particles that are difficult to remove. In underwater environment, due to the special lighting conditions, there are more random noises in the image, which affects the target recognition, so the removal of image noise becomes particularly important. This study uses nonlinear filtering of neighborhood pixels with better effect for underwater images.

Mean filtering is a simple linear smoothing filtering method, whose main idea is to replace each pixel value in a certain area with the average value of pixels in the image [17]. The basic steps to realize the mean filtering are as follows: First, a filtering window is established, that is, a filter window with a fixed size and a shape usually square or rectangle is selected, which can determine the size of the coverage area when the filter slides on the image. Secondly, slide the selected filtering window along the image, take the average value of pixels in each window, and then replace the pixel value in the center of the window with the average value. The main advantages of mean filtering are simple, easy to implement and short in time, but it may lead to loss of image details in the filtering process. Mean filtering is more suitable for scenes where noise is lightly smoothed, and less suitable for tasks that require image detail to be preserved. The effect of underwater image mean filtering is shown in Figure 4.

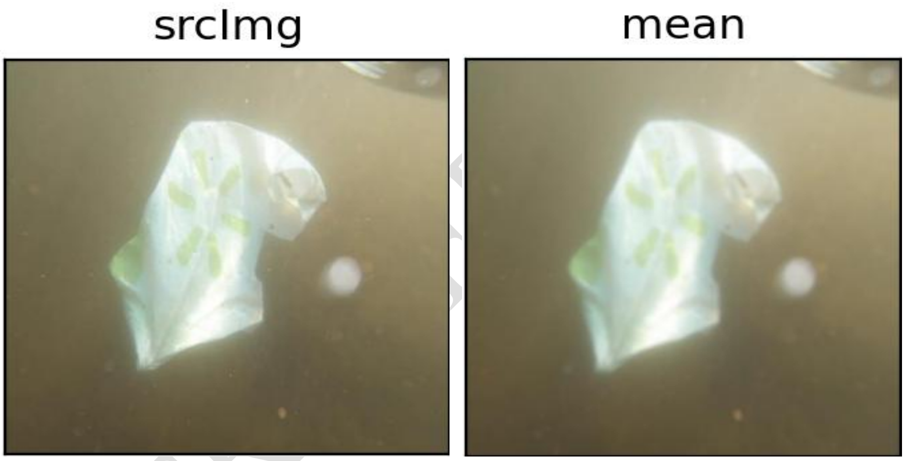


Fig4. Original Image and Mean Filtering Result

Median filtering is a nonlinear filtering method based on ranking. By selecting the median value instead of the average value, it is more suitable for removing discrete noises such as pepper and salt noise and Gaussian noise, with obvious effect [18]. Here are the steps to implement the median filter: Step 1: Create a rectangular mask, select an odd-sized rectangular mask, usually 3x3 or 5x5, to slide over the image. Step 2: Slide filter, slide the rectangular mask along the image, for each pixel selected by the mask, take the median value of all pixels in the mask range, and then use this median value as the new value of the current pixel. The third step: edge processing, for the pixels on the edge of the image, the value of the edge pixel is usually used as a reference for external expansion assignment, to ensure that the entire image can be processed.

The effect after mean filtering is shown in Figure 5

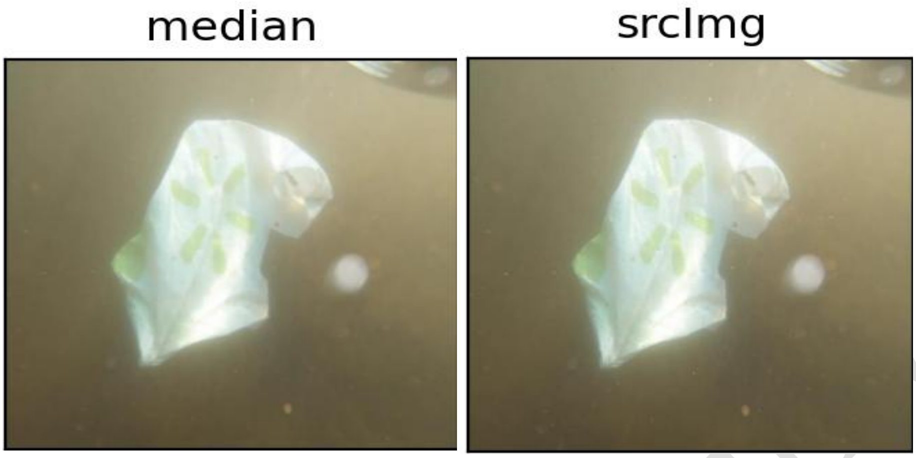


Fig5. Original Image and Median Filtering Result

In order to effectively solve the problem of image denoising, bilateral filtering becomes a very practical filtering method. It is a nonlinear filtering method by considering both spatial proximity and pixel approximation, combining spatial domain information and gray scale similarity. Bilateral Filtering is a nonlinear filtering algorithm based on the Gaussian filtering algorithm. It consists of two functions, the geometric space distance coefficient and the pixel difference determinant coefficient [19], and comprehensively considers the space domain and the pixel range domain. It has strong edge preservation, noise reduction and smoothing capabilities, and can retain more edge and detail information than Gaussian filters.

The following is the basic step of bilateral filtering: First determine the filter parameters, define two parameters, one to control the spatial similarity, the other to control the gray value similarity. These two parameters are usually expressed as the space standard deviation and the range standard deviation, respectively. They determine the filter's range of action and sensitivity to gray values. The filter window is then defined, and for each pixel in the image, a filter window centered on that pixel is created. The size of the window is usually determined by the spatial standard deviation, which is related to the spatial similarity. Then the weights are calculated, and for each pixel in the filter window, its spatial similarity and gray value similarity are calculated. This can be achieved by a Gaussian function, where spatial similarity and grayscale value similarity are determined by the spatial standard deviation and grayscale value standard deviation, respectively. The calculated weights are used to weight average the pixels in the window. Finally, filtering is performed, and each pixel in the window is weighted according to the calculated weight. In this way, the central pixel is replaced by a weighted average of similar surrounding pixels. The mathematical expression of the geometric space distance coefficient is shown in Formula 9:

$$w_d = exp\left(-\frac{(i-k)^2+(j-l)^2}{2\sigma_d^2}\right) \tag{9}$$

The mathematical expression of pixel difference determination coefficient is shown in Formula 10:

$$w_r = exp\left(-\frac{\|f(i,j)-f(k,l)\|^2}{2\sigma_r^2}\right) \tag{10}$$

The mathematical expression of bilateral filtering is shown in Formula 11, which is obtained by multiplying the above two functions:

$$H(i,j) = exp\left(-\frac{(i-k)^2+(j-l)^2}{2\sigma_d^2} - \frac{\|f(i,j)-f(k,l)\|^2}{2\sigma_r^2}\right) \tag{11}$$

Where, (k, l) is the central coordinate of the region currently convolved; (i, j) is the coordinate of the neighborhood pixel of the convolved region; σ_d and σ_r are the standard deviations of Gaussian functions. The function $f(x, y)$ represents the pixel value of the image at the point (x, y).

Compared with median filtering and mean filtering, bilateral filtering performs better. Its advantage is that it fully considers the spatial domain information and range information of image pixels. In image processing, bilateral filtering can effectively retain image edge information and remove noise at the same time. Its simple application and fast calculation speed make it widely used in various fields. Figure 6 shows the effect of bilateral filtering on underwater images. The effectiveness of this method stems from its ability to preserve image detail and edges while smoothing the image, making it a powerful denoising tool. In underwater image processing, bilateral filtering plays an important role in improving image quality and enhancing visibility.

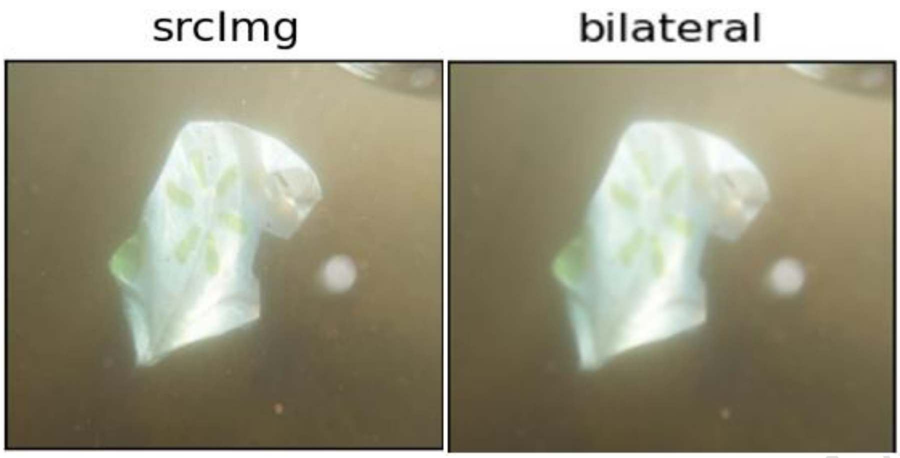


Fig 6. Original Image and Bilateral Filtering Result

3.4 Adaptive gamma correction

Gamma correction is a nonlinear operation of the gray value of the input image to make the gray value of the output image have an exponential relationship with the gray value of the input image [20], which is an image processing technology used to adjust the brightness and contrast of the image. The main functions include: brightness adjustment, by adjusting the gamma value, you can change the overall brightness of the image, so that the image is more consistent on different display devices; Contrast adjustment, gamma correction can also affect the contrast of the image, especially in the low gray value area, by adjusting the gamma value, you can enhance the detail of the low gray value. The gamma correction expression is:

$$T(l) = l_{max}\left(\frac{l}{l_{max}}\right)^{\gamma} \tag{12}$$

Where, $T(l)$is the intensity of the output image after gamma conversion; l is the gray value of each pixel of the image; l_{max} is the maximum gray value in the image; γ is the adjustment coefficient, and the shape of the gamma function can be adjusted .when $\gamma > 1$, the gray-level compression is carried out on the brighter part of the image, so that the gray value of these bright parts is relatively reduced, resulting in the overall darkening of the output result, which mainly affects the brightness of the image; When$\gamma < 1$,contrast enhancement is carried out on the darker parts of the image, so that the gray value of these dark parts is relatively increased, which mainly affects the contrast of the image and helps to strengthen the details in the image.

Traditional gamma correction is a global enhancement algorithm, which applies the same enhancement function to pixels of different gray levels, which may cause the problem of contrast distortion. In addition, the traditional gamma correction algorithm needs the user to set the adjustment coefficient manually, and the quality of each image is different, so the adjustment coefficient cannot be changed adaptively, thus affecting the image processing effect. To overcome these problems, an adaptive gamma correction [21] was introduced to replace the traditional algorithm. The main difference between adaptive gamma correction and traditional gamma correction is that it calculates corresponding gamma values according to different regions of the image, and uses different gamma values to adjust the brightness and contrast of the image, so as to obtain the image conforming to human visual characteristics.

In this study, the input image is converted from RGB color space to LAB color space. In the correction process, color components A and B remain unchanged, and adaptive gamma transformation is mainly performed on brightness component L to ensure the stability of color information while adaptively adjusting brightness. Set a brightness threshold D=15, when the brightness value of the image brightness component L is less than this value, the image is regarded as dark; When the brightness value is greater than this value, the image is regarded as brighter.

First, grayscale the original image and define the negative image $I^{'}(l)$ of the input image:

$$I^{'}(l) = 255 - I(l) \tag{13}$$

Where, $I(l)$ is the pixel gray value of input image I, that is, this step is to invert all input pixels.

Then define the image pixel weighted distribution function $P_w(l)$:

$$\begin{gathered} P_w(l) = P_{max}\left(\frac{P(l)-P_{min}}{P_{max}-P_{min}}\right)^{\alpha} \\ \alpha = \sum_{l=0}^{L-1} P(l) \end{gathered} \tag{14}$$

Where, $P(l)$ is the probability density function that can be calculated from Formula 6 according to the histogram information of the input image, and P_{max} is the maximum value of $P(l)$;P_{min} is the minimum value of $P(l)$.

Weighted cumulative density function $c_w(l)$:

$$c_w(l) = \sum_{l=0}^{L}\left(\frac{P_w(l)}{\sum P_w(l)}\right) \tag{15}$$

The adjustment coefficient $\gamma_{w1}(l)$ of the brighter image and the adjustment coefficient $\gamma_{w2}(l)$ of the darker image:

$$\begin{cases} \gamma_{w1}(l) = 1 - c_w(l) \\ \gamma_{w2}(l) = max(t, \gamma_{w1}(l)) \end{cases} \tag{16}$$

In the formula, the truncation threshold t is generally 0.5, which can prevent the loss of details in the higher gray level region during the gamma correction transformation.

The output result after correction is:

$$T_e(l) = round\left[l_{max}\left(\frac{l}{l_{max}}\right)^{\gamma_W(l)}\right] \tag{17}$$

The $round[*]$is a rounding operation, which can be divided into two cases: the input image is lighter or darker. When the input is a lighter image:

(1) According to equation 13, negative operation is applied to each pixel value of the input image to calculate its negative image I';

(2) The probability density function $P(l)$ ofI' is obtained, and the corresponding weighted distribution function $P_w(l)$is calculated according to equation 14;

(3) According to the obtained weighted distribution function, Formula 16 is used to calculate the corresponding adjustment coefficient $\gamma_{w1}(l)$ when the input image is bright;

(4) The adjustment coefficient is used to enhance the negative image, and then the enhancement result of the negative image can be calculated according to Formula 17;

(5) The enhanced result of the input image $I_e = round[255 - I_e{}']$,When the input is a dark image, the algorithm steps can be simplified as follows;

(1) The probability density function $P(l)$ of I^' is obtained, and the corresponding weighted distribution function $P_w(l)$ is calculated according to Formula 14;

(2) According to the obtained weighted distribution function, Formula 16 is used to calculate the corresponding adjustment coefficient$\gamma_{w2}(l)$ when the input image is bright;

(3) After enhancing the negative image using the adjustment coefficient, the enhancement resultI_e of the input image is calculated according to Formula 17.

The effect of underwater images processed by adaptive gamma correction algorithm is shown in Figure 7. The adjustment coefficient of adaptive gamma correction is adjusted according to the relationship between light and shade of the image. Through adaptive gamma correction of bright channels, different areas of the image can be adjusted more finely, which helps to maintain image details and avoid contrast distortion that may be caused by global enhancement. In addition, due to the adaptive nature, there is no need for the user to manually select the adjustment coefficient, and the algorithm can adapt to the features of different images more flexibly, thus providing better visual effects.

Fig 7. Original Image and Adaptive Gamma Correction Results

4 Conclusion

Based on the imaging of underwater images, this paper studies the optical imaging model of underwater images, describes the underwater imaging process, analyzes the influencing factors of imaging, provides a theoretical basis for algorithm design, and can be used to evaluate the correction effects of different algorithms on various influencing factors. Through the analysis of white balance algorithm, histogram equalization algorithm, bilateral filtering algorithm and gamma correction method, the underwater image quality and detail representation ability are improved, which is conducive to the sorting and application of underwater image resources, and provides an important support for underwater target recognition.

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