Study on Detection Image Processing Method of Offshore Cage

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Abstract. The paper aims to test the integrity of offshore cages. In this paper, offshore robots are used to collect video images. Through preprocessing methods such as color space conversion and Retinex algorithm of fusion-oriented filtering, the color distortion of the image is improved and the edge information of the image is maintained, so that the collected cage image is better recognized and calculated by the computer. And the paper uses the Canny algorithm to accurately locate the edge of the image, so that the boundary information can be reflected in more detail. In this paper, the adaptive threshold segmentation algorithm combined with mathematical morphology processing method is used to segment the offshore cage image, and extract the skeleton of the decomposed image to realize the detection of the integrity of the offshore net. Finally, a ROV equipped with a camera was used to verify the proposed method in a wave-flow water tank, which confirmed the effectiveness of the method and optimized the integrity recognition and image processing of the cage.

Keywords. offshore cage, image processing, guided filtering, image segmentation

1. Introduction
The area of the ocean is 3.6×10⁸km², and the potential for development and utilization of marine biological resources is huge. With the continuous growth of people's demand for seafood, in order to achieve the sustainable development of fisheries, offshore cage culture has gradually become the main development direction of marine aquaculture industry in China[1-2], as shown in Figure 1. According to statistics, about two-thirds of the losses in cage aquaculture are caused by fishing net damage. The damage of the fishing net not only causes unpredictable economic losses, but also causes severe ecological environmental problems. At present, in order to reduce the damage loss of the fishing net, the commonly used methods include changing the net regularly, or the divers often checking the cage to check the integrity of the net, inspecting the mooring system, detecting the accumulation of mud, etc. But these two methods are not only inefficient, but also have great security risks. Therefore, a more reliable and safer cage detection solution is needed to solve the key problem affecting the healthy development of offshore cage culture.

According to the practical application of offshore cage detection, this paper proposes a method of offshore net clothing integrity detection based on image processing technology. This method has the characteristics of non-contact and intelligent. Firstly, the paper analyzes the image of offshore cage net clothes. Through the analysis, it can be seen that: 1) Because the image acquisition environment is offshore, affected by the optical action of water body and the limitation of the shooting hardware
environment, the light is dim and uneven, and the image may be stored in the reflection point. 2) The surface of the fishing net is easy to be eroded because it is in offshore environment for a long time, which leads to the complex texture of the fishing net and the impurity of the mesh, and the noise interference will exist on the surface of the net. 3) The target of offshore net clothing is weak, and the image collected is often fuzzy, especially the edge information of the mesh is disturbed by impurities, and even the color deviation appears under the influence of offshore environment[3-4]. The captured image is shown in Figure 2.

According to the characteristics of offshore fishing net image, this paper proposes a method based on adaptive threshold segmentation combined with image morphology processing, which mainly includes the following three steps: 1) Image preprocessing: preprocessing the input image, including the conversion of color space and image, denoising and enhancement using Retinex algorithm of guided filtering, 2) Mesh extraction: the offshore net clothing image is segmented by adaptive threshold, and then morphological processing is carried out for the segmented image. Finally, the interference noise is removed from the segmented binary image, 3) Feature parameter extraction: after the elimination of interference binary image skeleton extraction, get the characteristic value. The flow chart of image processing is shown in Figure 3.

Figure 1. Detection of offshore cage

Figure 2. Image of offshore fishing net

Figure 3. Image processing flow chart

2. Image preprocessing of fishing net
For image preprocessing, this paper proposes Retinex algorithm based on guided filtering. Firstly, the color space of the image is converted, which greatly improves the problem of image color distortion. Guided filtering is used to estimate the illuminant component of the image, and the edge information of the image is maintained, which can effectively solve the "halo artifact" phenomenon of offshore fishing
net image. The experimental results show that the algorithm can better realize the offshore fishing net image preprocessing.

2.1. Conversion of color space
Due to the limitation of shooting conditions, there is always insufficient illumination in the offshore environment, which inevitably leads to the overall brightness of the offshore fishing net image to be dark. Therefore, in the case of low illumination image enhancement, the brightness of the image should be enhanced first. In HSV color space, hue, saturation and value directly correspond to human visual perception characteristics, and the correlation is low. Therefore, HSV color space model is used to improve the adverse effect of color distortion on later feature extraction. The HSV color space model is shown in Figure 4. In HSV space, the brightness component V is operated without direct operation of three primary colors, and the relationship between primary color phase and saturation is not changed, the processing image is shown in Figure 5.

![Figure 4. HSV color space model](image1)

In HSV color space, after the brightness of the image is enhanced by operating V value, histogram equalization is used to make the image evenly distributed on the whole gray level, so as to improve the contrast of the whole image. Moreover, the binarization threshold can be preliminarily determined through the histogram shown in Figure 6.

![Figure 5. Original image and HSV color channel](image2)

![Figure 6. Pixel distribution histogram](image3)

2.2. Illumination component estimation based on guided filtering
Referring to Retinex algorithm, this paper proposes an offshore image enhancement algorithm based on guided filtering, which effectively solves the problems of "halo artifact" and excessive enhancement processing in high contrast edge region of traditional Retinex algorithm, and mainly improves the color reality and image illumination component estimation. The algorithm flow chart is shown in Figure 7.

In this paper, the linear guided filter with smoothing and edge preserving function is used to estimate the illumination component. The least square method is used in the design of the filter. Through box filter and integral image technology, the time complexity is reduced and the gradient is...
maintained. Compared with bilateral filtering, it can estimate the illumination component more efficiently.

Guided filtering algorithm uses the guided image to calculate the output image, which can be the input image itself or other images. The algorithm is not only used in image smoothing, but also widely used in image defogging and offshore image processing. The scheme of guided filtering is shown in Figure 8.

$$R_v(x, y) = \log(I_v(x, y)) - \log(f(I_v(x, y)))$$ (1)

Where: $R_v(x, y)$ is the reflection component of the logarithmic format, $f$ is the guided filter function. Guided filtering can be expressed as a local linear model

$$q_i = a_k I_v + b_k, \forall i \in \omega_k$$ (2)

Where: $q_i$ is the gray value of linear transformation at $i$ pixel of image $I_v$ at window $\omega_k$, $k$ represents the central pixel of window $\omega_k$. In $\omega_k$, the coefficient $a_k$ and $b_k$ is a constant. Local linear coefficient $a_k$ and $b_k$ can be solved in the following ways:

$$a_k = \frac{1}{N_{\omega_k}} \sum_{j \in \omega_k} I_j^2 - u_k^2$$ (3)

$$b_k = (1 - a_k)u_k$$ (4)

Where: $u_k$ is the mean value of pixels in image window $\omega_k$, $\sigma_k$ is the standard deviation of pixels in image window $\omega_k$, $N_{\omega_k}$ is the number of pixels in window $\omega_k$, $\delta$ is the regularization parameter, which is used to balance the degree of smoothness and edge preservation, and the larger the value, the better the smoothness, but the worse the edge preservation. In order to obtain a stable $q_i$, it is necessary to average it and apply the linear model to the whole image:

$$f_j(I_v(x, y)) = \frac{1}{N_{\omega_k}} \sum (a_k I_v(x, y) + b_k)$$ (5)

3. Edge detection

The change of the physical characteristics of the target will cause the image edge to change. The physical characteristics include the brightness of the surrounding environment, the shape of the target and the reflection coefficient of the medium[6]. In the method used in this paper, the edge detection technology is used to extract the edge of the fishing net, so as to further analyze and calculate the integrity of the fishing net.
In this paper, Canny edge detection algorithm is used to extract the edge of the original image. The algorithm steps are shown in Figure 9. And compared with Laplacian edge detection results, the comparison results are shown in Figure 10. Compared with other edge detection operators, Canny operator transforms the process of edge detection into the problem of finding function extremum. In determining whether a pixel is an edge point, this paper does not simply according to the gradient operation structure of a pixel, but combines other pixels with processing pixels for comprehensive consideration. From the effect of extraction, Canny edge detection is more accurate and the boundary information reflects more detailed.

4. Adaptive threshold image segmentation
Image segmentation is a key step from image processing to image analysis. The meaning of image segmentation is to divide the image into several specific non overlapping regions according to the features of gray, color, texture and shape, so as to extract the required objects. Aiming at the problems of low contrast, uneven illumination and large background interference in offshore fishing net image, this paper adopts the adaptive maximum inter class variance threshold segmentation algorithm, which can be divided into the background part and the target part according to the gray characteristics. When the inter class variance is maximum, the threshold obtained is the optimal binarization threshold. Calculation formula of variance $G$:

$$G = W_0 \times W_1 \times (U_0 - U_1)^2 \tag{6}$$

Where: $W_0$ is the proportion of the background to the total number of pixels in the image, $W_1$ is the proportion of the total number of pixels in the image, $U_0$ represents the average gray level of background pixels, $U_1$ represents the average gray level of the target pixel, $G$ is the inter class variance value. When $G$ value is the maximum, traverse $t$ from $L$ gray levels. When $t$ is a certain value, the variance of foreground and background is the largest, which is the best threshold $t$ for segmentation. The binarization results under different $T$ are shown in Figure 11, and the optimal threshold $I$ among 100-150.

![Figure 9 Canny edge detection flow chart](image)

![Figure 10a) Original gray image b) Laplacian edge detection c) Canny edge detection](image)
5. Morphological processing and noise elimination

After the processing of the previous steps, the image still has a lot of noise and edge burrs. Therefore, this article chooses to use morphological open operation to further process the image. The opening operation is a process of erosion first and then expansion. Among them, in the process of erosion, the boundary of the object will be reduced to a small area, and the target area can be eliminated. The expansion makes the range of the target area become larger, which can merge the background points involved with the object of interest together, and make the target boundary move outward. It can be used to fill some holes in the target area and eliminate the small particle noise contained in the target area. The advantage of opening operation is that it can weaken the narrow part, remove the long and thin protrusion, edge burr and isolated spot, smooth the large object boundary, and can cut off the adhesive noise interference between the objects, at the same time, it can keep the object size unchanged. The mathematical expression is as follows:

$$\text{dst} = \text{open}(\text{src}, \text{element}) = \text{dilate} (\text{erode}(\text{src}, \text{element}))$$

After mathematical morphology processing, there are still short lines or isolated points that do not match the target. In this paper, the method of morphology combined with noise elimination is used to overcome this defect. In the MATLAB image processing, bwareopen() function can delete the object with small area. The basic idea of the function is to delete the object whose area is less than P in the binary image. The size of the area object to be deleted is controlled by setting the threshold value p, so as to eliminate the isolated noise in the offshore fishing net image. The experimental results of morphological processing and noise removal are shown in Figure 12, a is the original edge detection image, b is the morphological processing image, and c is the interference noise removal effect picture.

6. Feature parameter extraction

The characteristic image of the fishing net obtained through the above steps, the red line is the damage information of the offshore fishing net image, and the black part is the background information. Extract the infinite skeleton of the linear structure, and estimate the length of the linear damage by counting the number of pixels. Taking the resolution of the shooting image camera as a calibration, the actual length of the target can be estimated, and then information such as area can be obtained. The extraction diagram of the characteristic parameters of the fishing net is shown in Figure 13. It can be seen that this method can effectively extract the characteristic parameter values of the fishing net.
7. Conclusion
This paper conducts in-depth research on the enhancement and detection processing of the integrity image of the offshore aquaculture net cage fishing net, and proposes a new non-contact offshore fishing net detection method. This method can quickly and accurately obtain the damage characteristics of the fishing net, and thereby detect the location and extent of the damage of the fishing net. The simulation test is carried out in the pool as shown in Figure 14.

The specific algorithm is as follows: (1) In order to solve the problems of a lot of noise interference, blurred edge and low contrast in offshore fishing net images, a Retinex image enhancement algorithm based on multi-scale guided filtering is proposed to preprocess the offshore fishing net. Firstly, the offshore fishing net image is transformed into HSV color space, and then the brightness image is smoothed by the guided filter to estimate the illumination component of the image. (2) Combined with morphological processing method, Canny edge detection and adaptive maximum inter class variance threshold segmentation method are used to segment the enhanced image of offshore fishing net. The clear binary image and skeleton image of offshore net clothing are detected, and the mesh image is refined into single pixel width.

Through the experimental verification, the offshore image enhancement algorithm proposed in this paper not only effectively alleviates the problems of color deviation and "halo artifacts" in the high contrast edge region of Retinex image enhancement, but also effectively extracts the parameter eigenvalues through the extraction algorithm of parameter eigenvalues to detect the integrity of fishing nets in complex offshore environment.

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9. References
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