A Feature Extraction Algorithm Based on Structural Light in Sea-air Imaging

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Abstract. The distortion phenomena in sea-air imaging mainly include geometric distortion, color deviation and low contrast. In order to obtain the target information accurately, it is of great significance to study the distortion image correction. More feature information can be obtained by using grid structured light. However, the random fluctuation of water surface and the complexity of underwater imaging environment, the traditional corner detection algorithm can not effectively obtain the correct corner information. In this paper, a fast corner detection algorithm based on minimum kernel value (MRSFAST) is proposed. The experimental results show that compared with the traditional detection algorithm, the algorithm can extract the feature point information of the image in real time, which is of great significance to further realize the distortion image correction.

Keywords: Sea-Space Imaging, Corner Extraction, Structural Light, Minimum Kernel.

1. Introduction
At present, for sea-air cross-medium imaging image recovery [1-3], mainly divided into two categories. The first is to use statistics to iteratively register the image sequence, take the mean image as the reference image, and get the corrected image after multiple cyclic interpolation processing. This kind of method needs to obtain a video stream and process each frame image, the time complexity is high, the data volume is large, can not guarantee the real-time. The second is to model the fluctuating water surface, so as to compensate and repair the distorted image. This kind of algorithm has good real-time performance, but high environmental requirements.

By using structured light [4], the feature information of the image can be increased, and the relevant parameters of the distortion correction model can be estimated in real time combined with the standard structured light image, so as to realize the distortion image correction. Feature point extraction and matching is very important for real-time distortion image correction. Due to the random fluctuation of water surface and the complexity of underwater imaging environment, the traditional corner detection algorithm can not effectively obtain the correct corner information. In this paper, a fast corner detection algorithm based on minimum kernel value is proposed.
2. Feature Extraction Algorithm

2.1. The Energy Characteristic Distribution of Structured Photograph

Structural light projectors are usually composed of laser generators, cylindrical mirrors, etc. After the laser output Gauss beam passes through the cylindrical mirror, a light plane is projected to the surface of the measured object, and a grid fringe image [5] with three-dimensional information on the surface of the measured object is formed after the camera imaging. Hence, ideally, the structured light strip image can be approximated as a line-like structure with a gaussian-shaped gray distribution along the normal direction of the center line of the light strip, as shown in the figure 1(a). The one-dimensional mathematical model of the gray distribution of the image along the normal direction of the light strip with the center point of the light strip as the origin can be expressed.

$$I(x) = h * e^{-is^2}$$ (1)

![Figure 1. Gray scale distribution of light stripe section.](image)

The center of the light bar is the highest point of the function, satisfying:

$$2\int_{a}^{x_0} I(x)dx = \int_{a}^{b} I(x)dx$$ (2)

Where the coordinate of the center of the light bar; the a, b is the two boundaries of the one-dimensional light bar. Because the integrals on the left and right sides are equal, they can also be called the center of energy. Actually, due to the limitation of the camera gray sampling depth, the light bar gray distribution function will be shown in figure 1(b), which can also obtain the energy center point by Eq.(2). In fact, the light bar gray distribution function will be shown in figure 1. Obviously, the energy center points obtained by the two gray distribution functions through Eq.(2) are the same.

2.2. The Feature Extraction Algorithms

Harris algorithm is [6] proposed by C.Harris and M.J.Stephens based on the feature extraction algorithm of corner points. The basic principle is to take the corresponding pixel point as the center, select a certain size window, calculate the change of gray curvature in the pixel window area, and select the point with the largest change of curvature as the feature point. The mathematical model is as follows.

$$E(u, v) = \sum_{x,y} w(x, y)[I(x+u, y+v) - I(x, y)]^2$$ (3)

Where $E(u, v)$ represent gray level change, $w(x, y)$ represent window function, $I(x, y)$ represent image gray level.
Fast algorithm is [7] a fast feature extraction algorithm, focusing on the pixel p in the image, I is its gray value with three pixel sizes as the diameter of the circle, get the gray value of 16 pixels around the p, setting threshold t, when the absolute difference p the gray value of 16 pixels with 9 or more pixels and the center point is greater than the threshold t, and we define pixel p as feature points, as shown in Figure 2.

![Figure 2. The basic principle of Fast algorithm.](image)

As the random fluctuation of water surface and the complexity of underwater imaging environment, the corner information of the image can not be accurately extracted based on the traditional corner detection algorithm. The simulation results are shown in figure 3. The traditional corner detection algorithm can not guarantee the registration accuracy. Aiming at the above problems, this paper proposes a fast corner detection algorithm based on minimum kernel value, which can extract image feature point information in real time and accurately.

![Figure 3. Traditional corner detection algorithms.](image)

3. The MRSFAST Algorithm

3.1. Image preprocessing

Through morphological filtering, dark target information and image enhancement are eliminated, and the original image is separated to obtain distorted structured light image. The image preprocessing model is shown in figure 4.
3.2. Image preprocessing

Fast corner extraction algorithm based on minimum kernel value is based on FAST algorithm, which can accurately obtain feature point information of image. The specific flow of the algorithm is as follows:

1. Set the gray threshold $t$, window value $w$, determine whether the candidate points are feature points according to 16 features, and each feature state is -1, 0 and 1.
2. Determination of corner features using non-maximum suppression.
3. Eliminate partial error feature points based on distance thresholds. According to the corner distribution characteristics of grid structured light, there are only 4 corner points in the local neighborhood.
4. For the case where there are more than 4 corner points in the local neighborhood, an algorithm based on the similarity region of the minimum kernel value is proposed to eliminate the misjudged feature points on the grid line.

The minimum kernel value similarity region corner detection algorithm (MRSFAST) uses circular template, as shown in the figure 5, the pixel point located in the center of the circular window template waiting for detection is called the core point. The domain edge pixel points of the core point are divided into two sets: the region where the luminance value is similar to the luminance of the core point, that is, the kernel value similarity set and the luminance value are not similar to the luminance of the core point. Assuming a circular template radius of 3 pixels, the statistical edge detection pixel is 16.

![Figure 5. The Circular template.](image)

The kernel value similarity set is shown in figure 6. When the template moves on the image, the similar region is the largest when the circular template is completely in the background or target region, as shown in figure 6(a), and the similar region is the smallest when the core is at the corner, as shown in figure 2(d).

![Figure 6. The core value similarity set diagram.](image)
The minimum kernel value similarity region corner determination process mainly by moving the circular template, in turn compares the gray level of each pixel point in the template with the gray level of the template core, and determines whether it belongs to the kernel value similarity set. The discriminant function is as follows:

\[
c(r, r_0) = \begin{cases} 
1 & |I(r) - I(r_0)| \leq t \\
0 & |I(r) - I(r_0)| > t 
\end{cases}
\] (4)

Count the number of pixels with similar luminance values between the circular template and the core \(n(r_0)\). where \(D(r_0)\) is a circular template region centered on \(r_0\). Based on the above principle, corner judgment can be carried out quickly.

4. Analysis of measurement results

In order to verify the feasibility and effectiveness of this algorithm, we have carried out simulation tests under the same hardware conditions. The image used in this algorithm is randomly selected frame in image sequence, and the length of frame sequence is 100.

![Figure 7.](image)

**Figure 7.** The simulation analysis of FAST Algorithm and MSRFAST Algorithm.

The Figure 7 shows the simulation results of two corner detection algorithms. From the simulation results, the MSRFAST algorithm can correctly detect the feature points in the distorted image. Table 1 is a statistical result of underwater aerial image processing using MSRFAST algorithm. Table 1 shows that the detection accuracy of this algorithm is about 98%, which can accurately detect real-time images. Provide accurate corner information for further registration.

| Number of frames | Number of frames detected | Number of frames incorrectly detected | Misdetection rate (%) | Detection rate (%) |
|------------------|--------------------------|--------------------------------------|-----------------------|--------------------|
| 20               | 20                       | 0                                    | 0                     | 100%               |
| 40               | 39                       | 1                                    | 2.5%                  | 97.5%              |
| 60               | 59                       | 1                                    | 1.7%                  | 98.3%              |
| 80               | 78                       | 2                                    | 2.5%                  | 97.5%              |
| 100              | 98                       | 2                                    | 2%                    | 98%                |
5. Conclusions
As the random fluctuation of water surface and the complexity of underwater imaging environment, the traditional corner detection algorithm can not effectively obtain the correct corner information. In this paper, a fast corner detection algorithm based on minimum kernel value is proposed. The experimental results show that compared with the traditional detection algorithm, the algorithm can extract the feature point information of the image in real time, which is of great significance to further realize the distortion image correction.

Acknowledgments
This work was supported by the Guangxi National Science Foundation (grant No.2018JJA170185) and the School-level Research Projects of Hezhou University (No. 2018ZZK03). Yongfa Ling is the corresponding author.

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