A Corner Detection Algorithm Based on Regional Center of Mass in Imaging through Water Surface

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Abstract. Structural light active imaging can obtain more information about the target scene, which is widely used in image registration, 3D reconstruction of objects and motion detection. Due to the random fluctuation of water surface and complex underwater environment, the current corner detection algorithm has the problems of false detection and uncertainty. This paper proposes a corner detection algorithm based on the region centroid extraction. Experimental results show that, compared with the traditional detection algorithms, the proposed algorithm can extract the feature point information of the image in real time, which is of great significance to the subsequent image restoration.

Keywords: Imaging through water surface, Structural light, Corner Detection, Centroid.

1. Introduction
Corner detection is a method to obtain image features in computer vision system. It is widely used in motion detection, image matching, video tracking, 3D modeling and object recognition [1-3]. At present, the classic corner detection techniques include Harris corner detection algorithm [1], Fast corner detection algorithm [2], Surf corner detection algorithm [3] and so on.

When imaging through water surface, the random fluctuations of the sea surface cause great interference to the imaging, which will cause the distortion of the underwater or air scenes [4-6]. The distortion and blurring of images seriously affect people's subjective experience of visual observation and easily cause misjudgment of image content. For this type of image, the current corner detection method has some problems, such as missing detection, repeated detection, multiple detection and inaccurate detection, which cause interference to the subsequent image restoration and target recognition. In this paper, a corner detection algorithm based on regional center of mass is proposed.

2. The proposed method
2.1. Sobel Edge detection algorithm
The Edge detection operator utilizes the mutation properties of the image edge to detect the edges. It is mainly divided into two types: one is an edge detection operator based on the first derivative, detecting the gradient value. Such as difference edge detection, Roberts’s operator, Sobel operator and Prewitt
operator. The one is the second derivative edge detection operator, which detects the edge by seeking over zero in the second derivative. Such as Laplacian operator, LOG operator and Canny operator.

The Sobel operator [7] is in the form of a filter operator used to extract image edges. For each pixel of the digital image \{f(i, j)\}, we examine the weighted difference of the up, down, left, and right neighbors, with the nearest neighborhood weights. Accordingly, the Sobel operator is defined as follows.

\[
s_x = \left[ f(x + 1,y - 1) + 2f(x + 1,y) + f(x + 1,y + 1) \right] - \left[ f(x - 1,y - 1) + 2f(x - 1,y) + f(x - 1,y + 1) \right]
\]

\[
s_y = \left[ f(x ,y - 1) + 2f(x ,y - 1) + f(x + 1,y - 1) \right] - \left[ f(x - 1,y + 1) + 2f(x + 1,y - 1) + f(x + 1,y + 1) \right]
\]

\[
G(i, j) = \sqrt{s_x^2 + s_y^2}
\]

The convolution operator is shown in Figure 1.

\[
s_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, \quad s_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}
\]

Figure 1. The Sobel edge detection operator

Each point in the image is convoluted using two templates in Figure 1, \( s_x \) is the maximum vertical edge and \( s_y \) representing the maximum of the horizontal edge. The maximum of two convolutions is the output of the point, and the result is an edge amplitude image. Select the appropriate threshold \( TH \), if \( G(i, j) \geq TH \), \((i, j)\) is the step edge point, \{ \( G(i, j) \) \} is the edge image. The Sobel operator is spatially easy to implement, can smooth the noise, can provide accurate edge direction information, and thus works better when compared to the Prewitt operator and the Roberts operator.

2.2. Proposed method

Due to the random perturbation of the water surface, the absorption and scattering of the water body will cause the distortion and blur of the structural light image. This paper proposes corner detection algorithm based on the regional center of mass, which can effectively overcome the problem of noise sensitivity using the corner detection algorithms based on gray scale characteristics.

The algorithm first obtains the contour information of the original image based on the Sobel edge detection algorithm, searched through the maximum connected domain, the area is the target image; and then divides the connected domain algorithm (eight connected), crosses the image and marks, and then calculates the coordinates of each connected domain, in which the center of mass coordinate calculation formula is as follows:

\[
x_o = \text{round}\left(\frac{1}{N} \sum_{i=1}^{N} x_i \right)
\]

\[
y_o = \text{round}\left(\frac{1}{N} \sum_{i=1}^{N} y_i \right)
\]
Where $x_i, y_i$ represents the horizontal and longitudinal coordinates of the pixel point $i$ in the local connected domain respectively; $x_o, y_o$ is the horizontal and longitudinal coordinates of the center of mass in the local connected domain respectively. Then according to the number $n$ of edges of the structured optical grid and the azimuthal angle $\theta_i$ located in the center of mass, split the local regions for $n$ sub-regions. For example, if the structural light grid is a quadrangle, it needs to be divided into four sub-areas. The specific division criteria are as follows:

$$
(x_i, y_i) \in \begin{cases} 
A_1 & \theta_i = \arctan \frac{\Delta y_i}{\Delta x_i} \in [0, \frac{\pi}{2}) \text{ and } \Delta y_i \geq 0, \Delta x_i \geq 0 \\
A_2 & \theta_i = \arctan \frac{\Delta y_i}{\Delta x_i} \in (-\frac{\pi}{2}, 0) \text{ and } \Delta y_i \geq 0, \Delta x_i \leq 0 \\
A_3 & \theta_i = \arctan \frac{\Delta y_i}{\Delta x_i} \in [0, \frac{\pi}{2}) \text{ and } \Delta y_i \leq 0, \Delta x_i \leq 0 \\
A_4 & \theta_i = \arctan \frac{\Delta y_i}{\Delta x_i} \in (-\frac{\pi}{2}, 0) \text{ and } \Delta y_i \geq 0, \Delta x_i \leq 0
\end{cases}
$$

(6)

Where $A_1, A_2, A_3, A_4$ represents the sub-regions. $\Delta y_i = y_i - y_o, \Delta x = x_i - x_o$ are the shift difference between the pixel points and center of mass in the local sub-region respectively.

Finally, we calculate the distance between each point in each subregion and the center of mass according to the European distance formula. Then find out the pixel point with the largest distance that is the desired corner point. And so on, we find the full corners of the image. The specific algorithm specific process is shown in Figure 2.

![Corner detection algorithm based on regional center of mass](image)

**Figure 2.** The corner detection algorithm based on regional center of mass

### 3. Analysis of measurement results

To verify the feasibility and effectiveness of this paper algorithm, the proposed method is simulated using MATLAB ((MathWorks Co., USA)). The image dataset used by the algorithm in this paper is a sequence of image frames taken vertically down from the air, and the experimental apparatus is shown in figure 3. The frame sequence length used is 100 and a pixel size is 500 × 500.
Figure 3. The experimental device diagram of the algorithm

Figure 4. Performance Comparison of the different algorithms

Figure 4 shows the detection results of the proposed algorithm and the traditional corner detection algorithm. Random perturbation, absorption, and scattering of the water waveform will result in image blur and distortion as shown in Figure 4 (a). When imaging trough water surface, the traditional corner
detection algorithms are prone to error detection and uncertainty. This algorithm can correctly extract the image feature points through edge feature extraction.

| Number of frames | Number of frames detected | Number of frames incorrectly detected | Misdetection rate (%) | Detection rate (%) |
|------------------|----------------------------|--------------------------------------|-----------------------|--------------------|
| 20               | 20                        | 0                                    | 0                     | 100%               |
| 40               | 40                        | 0                                    | 0                     | 100%               |
| 60               | 59                        | 1                                    | 1.7%                  | 98.3%              |
| 80               | 79                        | 1                                    | 1.3%                  | 98.7%              |
| 100              | 99                        | 1                                    | 1%                    | 99%                |

| Number of frames | Number of frames detected | Number of frames incorrectly detected | Misdetection rate (%) | Detection rate (%) |
|------------------|----------------------------|--------------------------------------|-----------------------|--------------------|
| 20               | 20                        | 0                                    | 0                     | 100%               |
| 40               | 40                        | 0                                    | 0                     | 100%               |
| 60               | 59                        | 1                                    | 1.7%                  | 98.3%              |
| 80               | 79                        | 1                                    | 1.3%                  | 98.7%              |
| 100              | 99                        | 1                                    | 1%                    | 99%                |

Table 1. The statistical table of feature extraction results of proposed method

Table 2. Performance comparison with the traditional corner detection algorithms

| Running time /s | Fast algorithm | Harris algorithm | Proposed method |
|-----------------|----------------|------------------|-----------------|
|                 | 4.308          | 8.906            | 0.516           |

Table 1 is the statistical result of the image frame sequence detection in this paper algorithm. According to Table 1, the detection accuracy of this algorithm is about 99%, which can accurately detect the angle point of the image and is important for the study of subsequent image registration and three-dimensional reconstruction.

Table 2 is the comparison of detection time of single-frame image between the algorithm and traditional angle detection method. Available from Table 1, the algorithm proposed in this paper can improve the speed of image angle point detection. To sum up, the proposed algorithm ensures the detection effect, the speed of angle extraction and shortens the time of feature extraction.

4. Conclusions

Structural light active imaging can obtain more information about the target scene, and is widely used in fields such as image registration, 3D reconstruction of objects, and motion detection. Due to the random fluctuation of the water surface and the complexity of the underwater imaging environment, the traditional corner detection algorithms are unable to effectively obtain the correct corner information, and a corner detection algorithm based on regional center of mass is proposed in this paper.

Experimental results show that compared with the traditional detection algorithms, the proposed algorithm can extract image feature points in real time, which is important for further realizing image recovery and wave surface reconstruction.

Acknowledgments

This work was supported by the Guangxi Natural Science Foundation (grant No.2018JJA170185 and No.2018GXNSFAA294063), and the Professional Foundation of Hezhou University (No.HZUJS202006), and the School-level Research Projects of Hezhou University (No.2018ZZK03, No.2018ZZK07). Bijian Jian is the corresponding author.

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