A new fast corner detection method based on template matching

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Abstract. Corner detection is the basic link of camera calibration, and its detection accuracy will directly affect the accuracy of camera calibration. In order to improve the extraction precision of the corners of the board, this paper put forward a new checkerboard corner detection method. Two kinds of corner point prototype templates are constructed by using the characteristics of the checkerboard. The similarity between the pixel points and the corner points is calculated by convolution of the convolution kernel and the image. The degree of similarity is used to distinguish the corner points from the non-corner points. The non-maximum suppression algorithm and the gradient statistical algorithm further screen out the target corner points. The experimental results show that the method used in this paper can accurately and quickly detect the corner position and has strong anti-interference ability.

1. Introduction
Corner detection [1] is an important method to extract image features in computer vision. The definition of diagonal points [2] has not yet been given a strict mathematical definition. Generally, it can be considered as a prominent point in an attribute, such as the point with high intensity of brightness change in two-dimensional images, the intersection point of multiple edge curves or the local maximum point of curvature. For different applications, we can also define "corner" by ourselves, such as "feature point" or "interest point". Corner can effectively retain the important features of the image, eliminate redundant information, and improve the speed of information processing. Corner detection has a good application prospect in 3d vision reconstruction, moving target recognition and image matching.

2. Algorithm based
The checkerboard calibration board is widely used in the research of calibration because of its simplicity. There are four main types of corner points, L type [3], T type, Y type and X type [4]. The checkerboard corner points adopted in this paper are x-type corner points. Neither the original HARRIS [5] corner point detection algorithm nor SUSAN algorithm [6] can eliminate the corner points in the outer circle of the checkerboard. At present, most corner point improvement algorithms are based on algorithms such as HARRIS, SUSAN and the corner detection algorithm based on curve contour [7].

Andreas Geiger, Frank and Moosmann [8] proposed a corner detection algorithm based on growth, which would bypass the interference of image covering to grow the largest checkerboard. However, the calculation amount is large and mainly focuses on the checkerboard growth. Therefore, this paper will improve the algorithm based on this algorithm, improve the real-time and robustness of corner point detection, and remove the necessity of calculating the checkerboard growth, and focus on the accurate detection of checkerboard corner points.
3. Corner Detection

3.1. Principle of corner point detection

According to different corner features, common corner detection methods can be divided into two categories: edge feature and grayscale feature information. In this article the angular point X intuitive analysis found that the image after measure transform mainly presents two kinds of different model, a kind of parallel to the axis of corner, another with an Angle of 45 °, axes are shown in figure 1 below.

3.2. Building templates

Each corner prototype consists of four filter cores, which are clockwise divided into \{A, D, B, C\} four parts. The filtering kernel is used to convolute the image later. The focus of this paper is to use these two corner prototypes to calculate the corner similarity between each pixel and the corner, and the corner similarity at the pixel is defined by the maximum value of all the prototypes and fippings combination.

\[
C = \max(s_1^1, s_1^2, s_2^1, s_2^2)
\]

\[
s_1^i = \min(\min(f_A^i, f_D^i) - \mu, \mu - \min(f_C^i, f_B^i))
\]

\[
s_2^i = \min(\mu - \min(f_A^i, f_D^i), \min(f_C^i, f_D^i) - \mu)
\]

\[
R = \sum_{i=1}^{m} w_i z_i
\]

Where, \(f_x^i\) represents the convolution kernel \(X(= A, B, C, D)\) and the convolution response value of the corner prototype \(i(i=1, 2)\) at a pixel point. The convolution formula is shown in formula (1)-(4), where \(R\) is the response value at any point of the image, \(W\) is the convolution kernel coefficient, \(Z\) is the grayscale value corresponding to the coefficient, and \(mm\) is the total number of pixels contained in the convolution kernel. \(s_1^i, s_2^i\) Respectively represents the possibility of black and white on the diagonal of prototype 1.

According to the image convolution principle, when the convolution kernel selects the most similar part of the image to be convoluted, the higher the response value will be, and vice versa. According to the analysis of equation (1)-(4), if the response of any of the four convolution kernels is small, the value of Corner likelihood \(C\) of the corner points will be reduced, which is very effective in distinguishing non-corner points from corner points.

This method selects three template scale to meet the needs of different size board in the image, in parallel to the axis and coordinate axis Angle respectively present 45 ° Angle. The specific scale prototype (scale 12) is shown in figure 2.

3.3. Threshold processing

Threshold processing \([8]\) is intuitive, easy to implement and fast to calculate, which can quickly remove a large number of pseudo-corner points.
$$C(x, y) = \begin{cases} C(x, y), & C > g \\ 0, & C \leq g \end{cases} \quad (5)$$

As in equation (5), $g$ is the selected threshold, because the difference between quasi-corner and pseudo-corner is large. Based on a lot of experimental experience, the value of $g$ is set to half of the similarity $C$ of corner. That is, when $g = 0.5C$, the removal of pseudo-corner is good.

After threshold processing, a relatively clear Corner likelihood diagram is obtained.

3.4. **Sub-pixel Location**

In this paper, non-maximum suppression is used to locate corners. Finally, the sub-pixel-level coordinates of corners are obtained by using the directional gradient characteristics of corners. Ideally, the pixel $q$ is a point on the local neighbourhood of corner $p$, and $f_q$ is the image gradient vector of the pixel.

- When the pixel $q$ is in a flat area, Such as in equation (6).
  $$f_q^T (p - q) = 0 \quad (6)$$
- When the pixel $q$ is at the boundary, as in equation (6).

The above is the ideal state, but in reality, due to the influence of noise, exposure, occlusion and so on, the gradient direction is not ideal and the edge is not sharp enough. In this paper, corner point $p$ satisfies as in equation (7) in the neighbourhood $N_i(p')$ of corner point candidate set $p'$:

$$p = \arg \min_{p'} \sum_{q \in N_i(p')} (f_q^T (q - p'))^2 \quad (7)$$

Where, $N_i$ represents an $11 \times 11$ domain and adjacent pixels are automatically weighted by gradient size. The equation (7) is obtained by deriving middle a on the right side of equation (8) and making it equal to 0.

$$p = \left( \sum_{q \in N_i} (f_q f_q^T) \right)^{-1} \sum_{q \in N_i} (f_q f_q^T)q \quad (8)$$

The edge direction vectors $e_1$ and $e_2$ are improved by finding the minimum error of the corresponding gradient direction vector. As shown in equation (9).

$$e_i = \arg \min_{i} \sum_{q \in M_i} (f_q e_i)^2
eq 0$$

$$e_i^T e_i = 1 \quad (9)$$

Among them, $M_i$ is $M_i = \{q \mid q \in N, \Lambda m_i^T f_q \leq 0.25 \}$ (10)

As shown in equation (10). Where, $M_i$ is a set of adjacent pixels, which is aligned with the gradient $m_i = [\cos(\alpha_i) \sin(\alpha_i)]^T$ of mode $i$.

4. **Experimental results and analysis**

4.1. **Comparing this algorithm with other algorithms**

In this paper, the image is template-matched by constructing a corner prototype. The results show that both the accuracy of the corner extraction and the algorithm time are superior to the conventional algorithm. The corner detection experiments of Harris algorithm, SUSAN algorithm, Harris improved algorithm and the algorithm in this paper are carried out by using MATLAB software. Three chessboard
diagrams are taken to detect the corner points. The chessboard specifications are 9*12, 10*12 and 7*10, respectively, as shown in Figure 3.

![Chessboard pictures](image1)

Figure 3. Chessboard pictures

We perform corner detection on the checkerboard image in Figure 3, and the detection result of the (a) group image in Figure 3 is now shown in Figure 4.

![Corner detection results](image2)

Figure 4. 9 x12 Chessboard Lattice Corner Detection Algorithms Result Contrast Diagram

From Figure 4, it can be seen that the algorithm in this paper can accurately extract corners when detecting corners. In order to further analysis, respectively from two aspects of extraction accuracy and operation time to draw a histogram, as shown in figure 5 and figure 6, can be intuitive to see from the figure, in this paper, the algorithm to extract the accuracy of close to 100%, the running time of the algorithm compared with other algorithms, also has greatly improved. The comparison results show the superiority of this algorithm.

The number and accuracy of corners detected by these four algorithms are plotted as shown in Figure 5. And the Figure 6 shown the time-consuming of corner detection by these four algorithms.

![Comparison of corner detection accuracy](image3)

Figure 5. Comparison of corner detection accuracy of different expected specifications

![Comparison of running time](image4)

Figure 6. Comparison of running time of corner detection of different checkerboard specifications

### 4.2. Algorithm influencing factors

In order to show the practicality of this algorithm, the influence of this algorithm on corner detection will be explored from the light source and distorted image.

#### 4.2.1. Influence of light source on corner point detection

Because the light source has a great influence on the image quality, the unsuitable light source can greatly reduce the image quality. For example, the shadow will cause edge blurring and cause false detection, and the uneven light will cause difficulty in threshold selection. In this experiment, a group of pictures were selected, and the size of the board in the picture was 8*7. Only the intensity of the light source can be guaranteed to change when taking photos. We collected 20 groups of images for the
experiment, and randomly selected a group of experimental results for display, as shown in figure 8 below. As shown in the results, the algorithm in this paper can accurately locate the corner points under different light intensities.

4.2.2. Influence of light source on corner point detection
Now we choose the irregular chessboard chart for corner detection. The checkerboard is composed of black and white squares and diamonds of different sizes. Twenty chessboard diagrams of this type were selected for experiment, and a group of display results were randomly selected, as shown in Figure 10.

5. Conclusion
From the above comparison chart, we can intuitively judge that the algorithm in this paper can effectively detect corners, while the conventional corner detection algorithm has the problems of false detection and re-detection. Because of the rounded corner effect \(^{[10]}\) of Gauss convolution, Harris corner detection algorithm leads to the appearance of redundant pseudo-corners near ideal corners. As for the Susan corner detection algorithm does not need edge detection or gradient calculation, it has high efficiency and strong anti-interference ability. However, the Susan algorithm cannot effectively distinguish the inside-corner points and edge points in the checkerboard, resulting in a large number of pseudo-corner points. The Harris improved algorithm refers to the degree of similarity between the grayscale value of the central point of the detection window and the grayscale value of other pixel points in the surrounding neighborhood. Such similarity is described by the difference of its grayscale value. Harris corner improved algorithm results in more pseudo-corner points due to the aggregation of "corner points". The algorithm in this paper has a great advantage for the above-mentioned corner detection algorithm.

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