An Improved Harris Corner Detection Algorithm Based on Adaptive Gray Threshold

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Abstract: In view of the problem that the threshold value of Harris corner detection algorithm needs to be adjusted according to the specific image situation when judging whether the target pixel point is a corner point, and it is difficult to select the threshold value. An improved Harris corner detection algorithm is proposed. For improve the self-adaptability of the algorithm, adaptive threshold is adopted. Experimental results show that the improved algorithm is more accurate and stable than the original algorithm.

1. Introduction

At present, there are two kinds of corner detection algorithms: one is corner detection based on contour curve [1], such as kitchen-rosenfeld [2] and Freeman chain code.

Recent years, computer vision-based vehicle detection has received more and more attention; the other category is corner detection based on grayscale image, which is mainly used for corner detection on the calculation of image gradient and edge curvature, such as Moravec algorithm and Harris algorithm. In 1988, Chris Harris and Mike Stephens proposed the Harris corner detection algorithm [3]. Since the corner extraction algorithm based on gray information directly processes the gray value of each pixel in the image to obtain the corner information of the image, avoids the error introduced in the contour detection process, and has higher computing efficiency, so it has been widely concerned. Among them, Harris algorithm and SUSAN algorithm are widely used in this kind of algorithm. An obvious deficiency of Harris corner detection algorithm is that it is sensitive to threshold. Since the algorithm defines the pixel points whose gray value changes more than the threshold value as corner points in the detection process, and the threshold value is usually given based on experience, there will be great uncertainty. The detected corners also show some clustering phenomenon, that is, corners in one region are rare, while corners in another region are very dense.

2. Principle of corner point detection

Harris corner detection algorithm is proposed by Harris et al, which is an improved point feature extraction algorithm based on signal based on the original Moravec algorithm. Harris algorithm uses differential operation and autocorrelation matrix to detect corner points, which has the characteristics of simple operation, uniform and reasonable extracted corner features, stable performance and so on.[4] The differentiation operator can reflect the grayscale change of pixel points in any direction, and effectively distinguish corner points and edge points. It is assumed that the grayscale of image pixel points (x, y) is I (x, y), and the gray intensity change expression of window centered on pixel points moving u and v in x and y directions is shown in formula (1):

$$E(u,v)=\sum_{x,y} w(x,y)\left[I(x+u,y+v)-I(x,y)\right]^2 \tag{1}$$

Where, [u, v] is the offset of the window; (x, y) is the coordinate position of the corresponding pixel in the window. W (x, y) is a window function, and the simplest case is that the w weight coefficient corresponding to all pixels in the window is 1. But sometimes, we set the w(x, y) function to be a binary normal distribution with the center of the window as the origin. If the central point of the window is an Angle point, the grayscale change of the point should be the most dramatic before and after moving, so the weight coefficient of the point can be set to be larger, indicating that the point contributes more to the grayscale change when the window moves. The weight coefficient of these points can be set as a small point to show that this point contributes less to the change of gray level. Therefore, we naturally think of using binary gaussian function to represent the window function. Generally, window functions have the following two forms, as shown in figure 1 below:

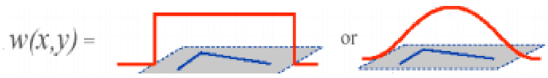

Figure 1. The window function

Formula (1) is expanded by Taylor formula to get formula (2):

$$\begin{aligned} &\sum [I(x+u, y+v) - I(x,y)]^2 \\ &\approx \sum [I(x,y) + uI_x + vI_y - I(x,y)]^2 \\ &= \sum u^2 I_x^2 + 2uvI_xI_y + v^2 I_y^2 \\ &= \sum \begin{bmatrix} u & v \end{bmatrix} \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} \\ &= \begin{bmatrix} u & v \end{bmatrix} \left(\sum \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix} \right) \begin{bmatrix} u \\ v \end{bmatrix} \end{aligned} \tag{2}$$

Therefore, equation (1) is transformed into (3):

$$E(u,v) \cong [u, v] \quad M \quad \begin{bmatrix} u \\ v \end{bmatrix} \tag{3}$$

Where M is:

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_xI_y \\ I_xI_y & I_y^2 \end{bmatrix} \tag{4}$$

It is generally assumed that the characteristic value of M is lambda 1 or lambda 2.

(1) When the number of lambda 1 or lambda 2 is small, the area detected by the window is considered to be flat.

(2) When the difference between lambda 1 and lambda 2 is large, the area detected by the window is considered to be flat.

(3) When both lambda 1 and lambda 2 are large and their values are relatively similar, the area detected by the window can be considered as a corner point.

Of course, such calculation is very large, because almost every point in the image needs to carry out an eigenvalue calculation, and the general calculation method is based on the following empirical formula:

$$R = \det M - a(\mathrm{trace}M)^2 \tag{5}$$

Where: detM is the determinant of M; traceM is the trace of M; R is the angular response value;a is the empirical constant, and the general value range is (0. 4, 0. 6). When R exceeds a set threshold, it can be considered as a corner point; otherwise, it is not. [5]

3. Improved algorithm

When Harris algorithm is adopted to extract corner points from an image, it is necessary to set a fixed threshold for continuous debugging to obtain better results. However, the threshold set may not be applicable to all other images, and it needs to be re-debugged. Considering the universality of the algorithm, the algorithm itself needs to be able to calculate the appropriate threshold. The improved algorithm firstly blocks the image and avoids the large area of out-of-bounds blocks. In order to ensure as much as possible the existence of corner points in each image after partitioning. We first select a threshold value M large enough to use Harris algorithm to select corner points in each pixel point of the entire image. Corresponding to this M was elected to the angle of each piece of the image point of interest in pixel value included in the array to M_{ij}, j said iteration steps, and will be ordered array from big to small. And sort the array from large to small. I means the element in the array corresponding to the ith block, then we select the iteration step length is k = 0.01, let M_{ij} according to the successive iteration step length decreases, until M_{ij} for most I stop at the establishment of iteration, thus guarantee the almost every piece of the image is angular point. Then, the threshold value T is defined as p times of the minimum M_{ij} value, that is, $T=p\times M_{ij}$. From the point of view of statistics, a series of images including various scenes were selected for experiments, and the set p value was constantly adjusted. The comparison results showed that when p was taken as the empirical value [0.005, 0.015], almost all corner points could be tested, and fewer pseudo-corner points were generated.

The improved algorithm first traversal the pixel points that need to be processed with the sliding window to get the value of interest, then iterate to find the best threshold, and finally process the block image to calculate the corner point position. The improved algorithm simplifies the complicated calculation process, and the calculated threshold is adaptive.

4. Analysis of experimental results

The experiment was run on the environment of opencv3.4.0 and vs2017. The triangular house was taken as an example for corner point detection. The original image is shown in figure 2 and figure 3. Since the pixel condition of each image is different, the detection result will be biased when fixed threshold is used for detection. As shown in figure 4 and figure 5 below, it is a standard detection with a threshold of 80. Although corner points can be detected in figure 2, many pseudo-corner points can be seen from the figure. However, for figure 3, the corner points could not be accurately detected, and the result showed a full screen of red. The reason was that the threshold was too small, and the program determined that all pixels were corner points.

After the improved corner detection algorithm is adopted, the experimental results of figure 2 and figure 3 are shown in figure 6 and figure 7. No matter which original picture is used, the accurate threshold value can be obtained to detect corner points further and remove some pseudo-corner points.

Figure 2. The original image one

Figure 3. The original image two

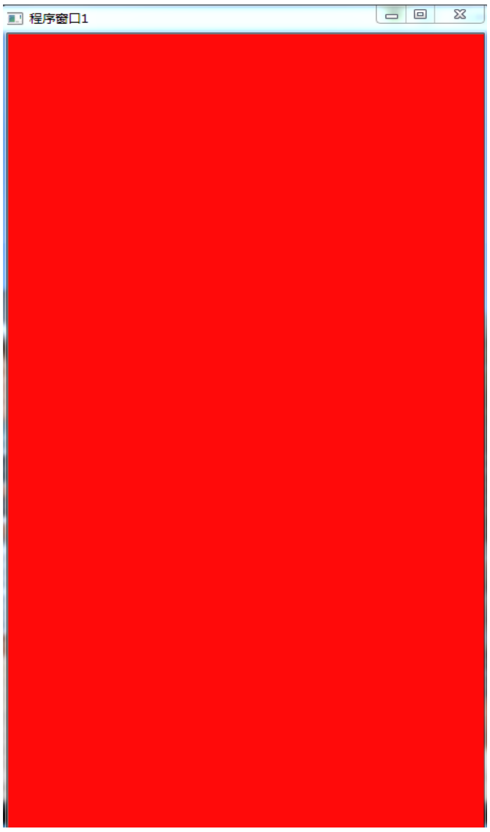

Figure 4. Corner detection diagram one

Figure 5. Corner detection diagram two

Figure 6. Improved corner detection diagram one

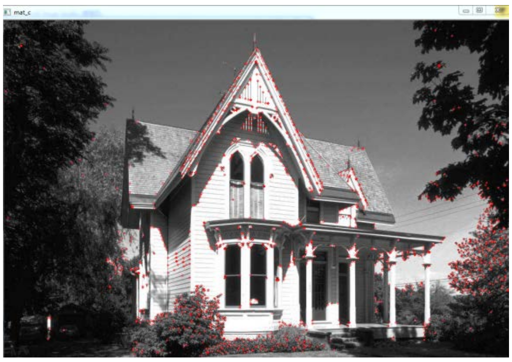

Figure 7. Improved corner detection diagram two

5. Conclusion

For some disadvantages of Harris corner detection algorithm, including will appear in the corner to extract angular point, and the problems in setting up the fixed threshold, is proposed based on Harris corner detection algorithm of adaptive threshold algorithm. Harris corner detection algorithm is not affected under the premise of calculation is simple and stable, block diagonal point are first pretreatment, select candidate angular point, and get the candidate corner minimum threshold, finally USES the adaptive threshold, improve the adaptability of the algorithm. It can be seen that the original Harris algorithm can detect a lot of pseudo-corner points and run for a long time at the same time. However, the improved Harris algorithm greatly reduces the running time of the program, improves the real-time performance, improves the accuracy of corner point detection and reduces pseudo-corner points.

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