Image Matching Algorithm Based on Improved ORB Feature Extraction

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Abstract. Ambient illumination is an important factor affecting the high mismatching rate of single threshold image matching algorithm. Therefore, this paper proposes a local dynamic threshold extraction algorithm. This algorithm needs to perform light homogenization processing in the image preprocessing stage and calculate the appropriate threshold of each pixel for feature point judgment during feature extraction, which can effectively alleviate the problem of missing extraction and multiple extraction during feature extraction of a single threshold.

Keywords: Illumination · Illumination homogenization · Feature extraction · Dynamic local threshold

1 Introduction

In recent years, image recognition technology in computer vision technology is very popular and widely used in many fields of life. Image matching algorithm based on image feature points is a common technique. With the development of The Times, the requirements for image matching algorithms are becoming increasingly strict. Strong robustness, good real-time performance and fast calculation rate are the important basis for measuring image matching algorithms.

The ORB (Oriented FAST and Rotated BRIEF) algorithm [1] is one of the most popular algorithm in image matching algorithm, it is famous for its calculation speed, and therefore more conspicuous in real time. ORB algorithm consists of two parts: FAST feature extraction algorithm [2] and BRIEF feature descriptor algorithm [3]. ORB algorithm is greatly affected by ambient lighting when extracting feature points. Feature points extracted from the same image under different lighting conditions will vary greatly, resulting in a high mismatching rate for image matching. Many scholars at home and abroad have proposed a variety of improved algorithms to make ORB algorithm have better illumination robustness. In literature [4], the author proposed to combine SURF algorithm [5] with ORB algorithm, so that the feature points extracted by ORB algorithm have the better robustness of SURF algorithm. Literature [6] improves the robustness of the algorithm by combining SIFT [7] algorithm with ORB algorithm. These two improvements have improved robustness, but they are not ideal in terms of computational

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efficiency and real-time performance. Literature [8] combines the k-means clustering algorithm with the feature detection algorithm [9], classifies the feature points, and then sets the threshold according to the classification results. However, this method greatly increases the computational complexity and is not applicable in the field where the real-time requirement is high.

In this paper, before extracting feature points, light homogenization is carried out to reduce the influence of light on image feature extraction. In the feature extraction stage [10], the first step is to determine the local threshold of gray scale fluctuation to determine whether the pixel point is in sensitive area. The second step is to set the threshold for the pixels in the sensitive area, otherwise the traditional fixed threshold is used.

2 The Original ORB Algorithm

2.1 FAST Feature Extraction Algorithm

FAST feature points are widely used because of their high computational performance, but FAST feature points have no directional feature, so the ORB algorithm adopts the grayscale centroid method to improve this, which is called oFAST algorithm (Oriented FAST). The gray-scale centroid algorithm calculates the centroid within the radius r by calculating a moment. The vector formed by the center of the circle and the center of mass is the directional property of the feature point.

In a 5 × 5 image block, the element expression of the moment of the corresponding image is shown in formula (1):

$$m_{pq} = \sum_{x,y} x^p y^q I(x, y) \tag{1}$$

Where, I(x, y) is the image grayscale expression used to calculate the image grayscale value of this point. X and y are at [−r, r], r is the radius of the image, and here it is [−3, 3].

Then the center of mass of the image window can be expressed as formula (2):

$$C = \left(\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}} \right) \tag{2}$$

Where, when p = q = 0, m_00 is the sum of all the gray values of the image block; When p = 1, q = 0, you get m_10; When p = 0, q = 1, you get m_01; M_10, m_01 is the first order matrix, m_00 is the zero order matrix.

Then the Angle of the whole image window, namely the direction of the feature point, can be expressed as formula (3):

$$\theta = arc\ \tan(m_{01}, m_{10}) \tag{3}$$

When the graph is a binary image, m_00 is the area that can be represented as the image. If the gray value of the image is regarded as the weight, then the center of mass is the center of mass of the image, that is, the weighted center of the whole gray value.

2.2 BRIEF Feature Descriptor Subalgorithm

RIEF descriptor is a binary descriptor, which has an incomparable speed advantage in the image matching stage. However, there are also big drawbacks. BRIEF does not have rotation invariance. The ORB algorithm makes use of the feature point orientation feature obtained by the improved FAST algorithm. It first rotates the descriptor obtained by the BRIEF algorithm, and then discriminates the binary code, so that the descriptor has rotation invariance. The improved BRIEF called rBRIEF (Rotated BRIEF). Suppose you have a smooth the image, the size of S × S neighborhood p, tau test:

$$\tau(p;\, x,\, y) \;=\; \begin{cases} 1 : I(p,\, x) \;<\; I(p,\, y) \\ 0 : I(p,\, x) \;\geq\; I(p,\, y) \end{cases} \tag{4}$$

Where, I(p, x) represents the pixel gray value of the smoothed image neighborhood p at point x = (u, v)ˆT.N_d (x, y) point pairs are selected to form bitstream binary descriptors of n_d dimension:

$$f_n(p) \;=\; \sum_{1 \leq i \leq n} 2^{i-1} \tau(p;\, x_i,\, y_i) \tag{5}$$

There are three options for n_d, 128, 256, and 512 (16, 32, and 64 bytes). Considering the generation rate, distribution and accuracy of bitstream binary descriptors, the 256-dimensional descriptors have the best comprehensive performance. To overcome the lack of rotation invariance in the BRIEF descriptor, the ORB algorithm takes advantage of the orientation of oFAST feature points to rotate the BRIEF descriptor in its main direction. The following is the implementation process: For any feature point, the location information in the neighborhood of 31 × 31 is the set of n pairs of points ((x)_i, y_i)), and they are represented as a matrix of order 2 × n:

$$S = \begin{pmatrix} x_1, \ldots, x_n \\ y_1, \ldots, y_n \end{pmatrix} \tag{6}$$

The corresponding rotation matrix R_ is expressed by using the principal direction theta of the characteristic points of oFAST:

$$R_\theta = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \tag{7}$$

The matrix S is rotated through the matrix R_ to get a new matrix S:

$$S_\theta = R_\theta S \tag{8}$$

RBRIEF description subexpression with rotation invariance:

$$g_n(p,\, \theta) \;=\; f_n(p) | (x_i,\, y_i) \;\in\; S_\theta \tag{9}$$

3 This Article Improves the ORB Algorithm

3.1 Image Preprocessing

The importance of image pre-processing for image feature extraction is self-evident. A high-quality image can greatly reduce the external interference for the subsequent image feature extraction and image feature description. In this paper, adaptive threshold determination is required for feature extraction, and ambient light has a strong influence on threshold selection, which requires light homogenization in the image pre-processing stage. The process of light homogenization is as follows:

The multi-scale gaussian function is used to remove the illumination component of the scene [11],

construct a two-dimensional gamma function to adjust the parameters of the two-dimensional gamma function based on the distribution characteristics of the light component, reduce the brightness value of the over-intense illumination region, and increase the brightness value of the over-dark illumination region, so as to finally realize the adaptive correction processing of the uneven illumination image [00]. The illumination component can be obtained by convolving the gaussian function with the original image [12].

$$G(x, y) = \lambda \exp\left(-\frac{x^2 + y^2}{c^2}\right) \tag{10}$$

In the formula, G is the gaussian function, c is the scale factor, and is the normalization constant, so that the gaussian function G(x, y) satisfies the normalization conditions.

Light component:

$$I(x, y) = F(x, y)G(x, y) \tag{11}$$

Where, F(x, y) is the input image, and I(x, y) is the estimated illumination component.

$$O(x, y) = 255\left(\frac{F(x, y)}{255}\right)^{\gamma}, \gamma = \left(\frac{1}{2}\right)^{\frac{m-I(x,y)}{m}} \tag{12}$$

The two-dimensional gamma function O(x, y) is the output image brightness value after correction, F(x, y) is the source image, where is the index value of brightness enhancement, and m is the brightness mean of the illumination component. In order to avoid interference between RGB channels, the whole processing process needs to be conducted in HSV color space, where the brightness component V is processed, and finally transformed from HSV space to RGB space.

The flow chart of the whole process is as follows:

3.2 FAST Adaptive Threshold Feature Extraction

FAST when making feature point extraction, first traverse each pixel of the image point, is the sole criterion for judging whether pixels feature points in the current pixel as the center of the circle draw three pixels for the radius of a circle (16 pixels circle, see

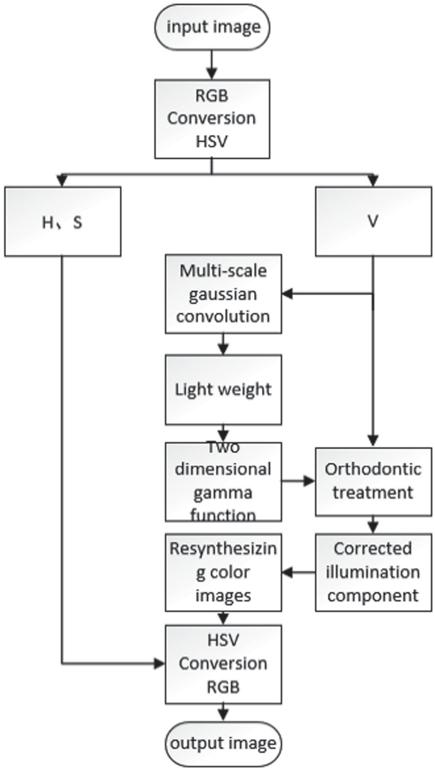


Fig. 1. Flow chart of illumination homogenization

Chart 1), statistical circle on 16 pixels and the center pixel gray value of absolute value of difference, if there are nine consecutive pixels in the circle and the center pixel of the difference between absolute value is greater than the threshold T set beforehand, is considered center pixel is feature points (Fig. 2).

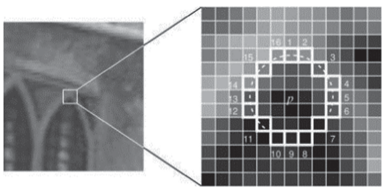


Fig. 2. Pattern diagram of feature extraction

FAST feature extraction USES a single threshold to determine the feature points. In this way, the feature points extracted are densely distributed and the number of redundant feature points is large, which is not conducive to the description of feature points and affects the result of feature matching. In this paper, the location information of the target pixel is determined when the feature points are extracted, and whether there are obvious changes in the pixel gray level in a certain size area of the pixel to be detected. According to this change, the detection area is divided into three categories: ignored area, ignored area and ignored area. The ignored region means that there is no gray level change in the region where the pixel is located, and no feature points are extracted in this region. The unfocused region refers to the region where the pixel is located, and the gray level change range is not obvious. The threshold value of feature point extraction in this region adopts the threshold value of the original ORB algorithm. The attention region refers to the region where the pixel is located where the gray level changes greatly, and the dynamic threshold is adopted to set the threshold to extract the feature points according to the gray level of the region.

Set the current pixel point as P, and select the threshold value in a window with a size of 7 * 7 centered on the pixel point P.

$$T(x_i, y_j) = \begin{cases} t_1, \ if \ (MAX - MIN) < S; \\ pass, \ if \ MAX = MIN; \\ t_2, \ if \ (MAX - MIN) \geq S \end{cases} \tag{13}$$

Where, T(x_i, y_j) refers to the threshold of determining whether the pixel point at (I, j) is the feature point. S is the measure to judge the range of gray level change in the region, S = 15. T_1 and t_2 are two different thresholds, t_1 = 10, and t_2 is the adaptive threshold.

$$t_2 = c\frac{\sum_{i,j=1}^{i,j=7} I(i, j) - I_{max} - I_{min}}{I_\alpha} \tag{14}$$

Where, I_max is the maximum pixel gray value in this window; I_min is the minimum pixel gray value in this window; I_ is to go out the maximum and minimum of the remaining 47 pixels grayscale average; C is the adaptive parameter and the percentage of the empirical threshold in the absolute pixel gray contrast in the window. The test shows that the feature points selected when c is 0.18 are more stable.

The improved FAST feature extraction process is as follows:

1) traverse the image pixel points and judge the gray level changes in the 7 * 7 neighborhood centered on the pixel points;
2) if the gray level does not change, the feature point extraction will not be carried out in this area;
3) if the change amplitude of gray scale is less than S, the fixed threshold is used for feature point extraction;
4) if the change range of gray level is greater than S, the adaptive threshold is used for feature extraction

4 Experimental Simulation and Analysis

In order to verify the effectiveness of the algorithm in this paper, the algorithm was verified in the hardware test environment of windows10 operating system, Intel(R) Core(TM) i7-6700hq CPU and memory of 8G, and in the OpenCv2.4 computer vision library and vs2017 development environment.

4.1 Image Feature Point Extraction Experiment

Feature extraction comparison between ORB algorithm and proposed algorithm (in order to visually and clearly compare the extraction effects of the two algorithms, non-maximum suppression is not performed here).

It is obvious from Fig. 3 that the feature points extracted by ORB algorithm are largely clustered and overlapped. It can be seen from Fig. 4 that the feature points extracted by the algorithm in this paper are less overlapped and clustered than those in Fig. 3. Intuition does not mean that the algorithm in this paper is better than the ORB algorithm in extracting feature points. Five experiments have been done here for time-consuming comparison (Table 1).

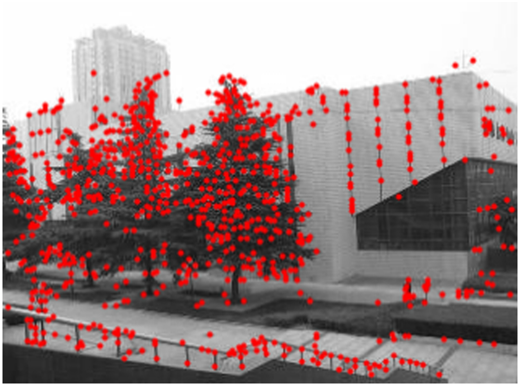


Fig. 3. Effect diagram of orb algorithm extracting feature points

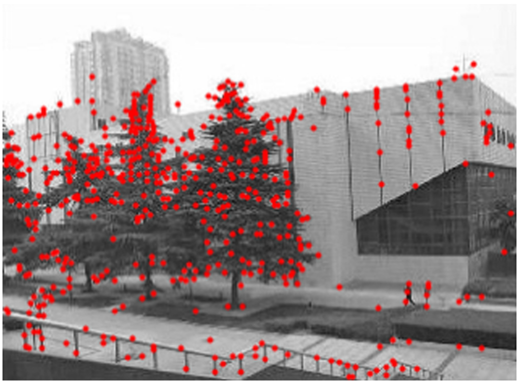


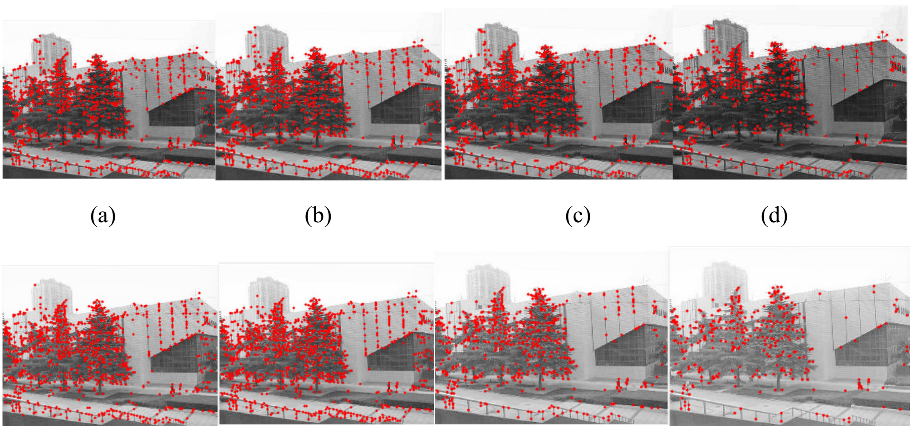
Fig. 4. Effect diagram of feature points extracted by the algorithm in this paper

To compare the ORB algorithm and the proposed algorithm in extracting feature point differences under different ambient lighting conditions, reduce the illumination of the original image by 10%, 20%, 40% and 80%, and enhance the illumination by 10%, 20%, 40% and 80%, respectively.

Table 1. Comparison of the time taken to extract feature points between the ORB algorithm and the algorithm in this paper

Experimental group	ORB algorithm	Algorithm In this paper	Take down than
1	1.485302	1.111101	25.19%
2	1.248731	1.054183	15.58%
3	1.199899	0.978244	18.47%
4	1.123802	0.919201	18.21%
5	1.151884	0.971725	15.65%

In Fig. 5, (a) the extraction result diagram with the original image reduced by 10%, (b) the result diagram reduced by 20%, (c) the result diagram reduced by 40%, (d) the result diagram reduced by 80%, (e) the result diagram enhanced by 10%, (f) the result diagram enhanced by 20%, (g) the result diagram enhanced by 40%, (h) the result diagram enhanced by 80%. In Fig. 6, (1) the extraction result diagram shows a 10% reduction in brightness of the original image, (2) the result diagram shows a 20% reduction in brightness, (3) the result diagram shows a 40% reduction, (4) the result diagram shows an 80% reduction, (5) the result diagram shows a 10% increase, (6) the result diagram shows a 20% increase, (7) the result diagram shows a 40% increase, and (8) the result diagram shows an 80% increase (Table 2).

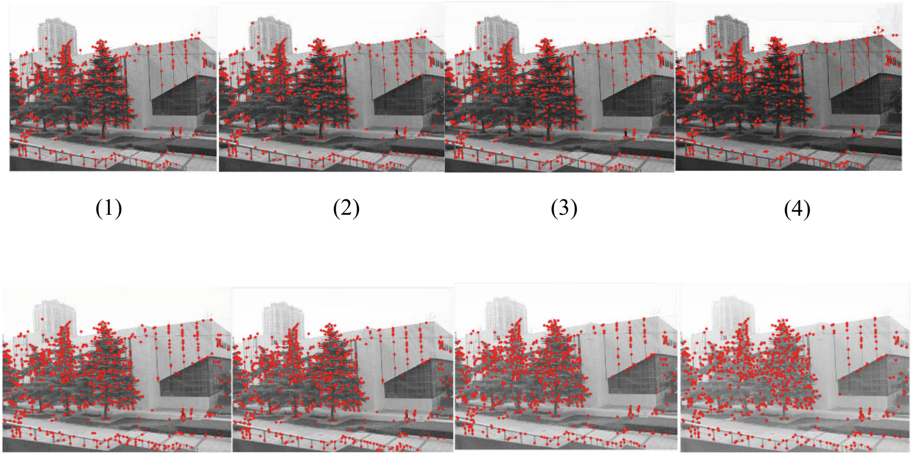


(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 5. ORB algorithm extracts feature points with different ambient brightness

As you can see, the number of feature points extracted by the ORB algorithm changes dramatically as the illumination changes in the environment. This algorithm is more stable than the ORB algorithm when illumination changes. And extracting feature points is faster than the ORB algorithm (Fig. 7).



(1) (2) (3) (4)

(5) (6) (7) (8)

Fig. 6. The algorithm in this paper extracts feature points with different ambient brightness

Table 2. Variation table of ORB algorithm feature points under different ambient lighting conditions

Experimental group	BRIGHTNESS CHANCE	Quantitative ORB characteristics	Feature points in this algorithm	The ORB time-consuming	The algorithm in this paper takes time
1	+10%	597	543	1.76524	1.21317
2	+20%	499	531	1.63414	1.19782
3	+40%	420	549	1.59905	1.18755
4	+80%	334	527	1.52381	1.24416
5	−10%	638	556	1.81021	1.21869
6	−20%	544	546	1.73501	1.27718
7	−40%	403	529	1.65032	1.31011
8	−80%	267	557	1.72591	1.27054

4.2 Image Matching Experiment

Use the ORB algorithm and the algorithm in this article for feature matching. Figure 8 is the ORB algorithm matching result graph, and Fig. 9 is the algorithm matching result graph of this paper (Tables 3 and 4).

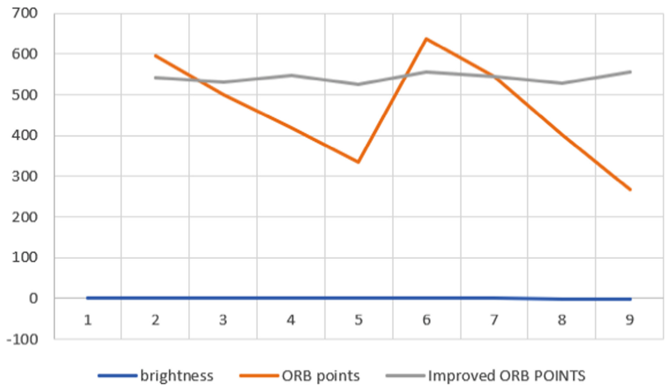


Fig. 7. ORB algorithm and the algorithm in this paper extract feature point comparison line graph

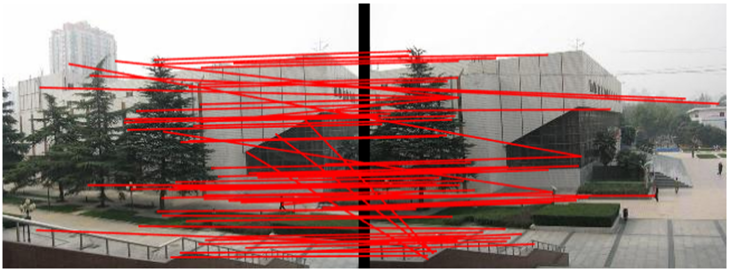


Fig. 8. ORB algorithm matching result diagram

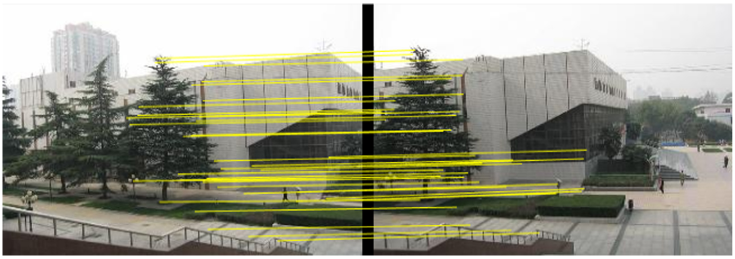


Fig. 9. Results of algorithm matching in this paper

Through the above data comparison, the feature point extraction algorithm proposed in this paper can effectively improve the speed of the algorithm, and at the same time, it can also have better matching accuracy under the changing ambient light.

Table 3. ORB algorithm match table

Experimental group	Successful logarithmic	Match the logarithmic	Precision
1	102	135	75.56%
2	96	129	74.42%
3	109	142	76.76%
4	85	114	74.26%
5	91	111	81.98%

Table 4. Algorithm matching table in this paper

Experimental group	Successful logarithmic	Match the logarithmic	Precision
1	77	91	85.72%
2	74	89	83.15%
3	81	100	81.00%
4	85	105	80.95%
5	71	91	81.98%

5 Conclusion

This paper proposes an improved ORB feature extraction algorithm, which has the following advantages compared with the original ORB algorithm:

1) it combines adaptive threshold and fixed threshold, which can effectively alleviate the problem of too dense and overlapping ORB feature extraction;
2) before extracting the features, the region was determined. If the gray level is consistent and the region has not changed, the feature extraction will not be carried out. Compared with ORB traversing each pixel, the extraction speed can be accelerated;
3) before feature points are extracted, light homogenization is carried out to reduce the difficulty of extraction caused by light changes.

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