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SIFT image matching algorithm in view of improved SUSAN operator and affine invariance

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Abstract. To improve the matching efficiency of SIFT algorithm, proposing a SIFT image matching algorithm, which in view of improved SUSAN operator and affine transformation. in view of the improved SUSAN operator to extract feature points, using Gabor filter smooth the image, improving feature point position, direction resolution and noise robustness; in view of affine transformation invariance, eliminating mismatched points. Experiments show that the matching efficiency of the algorithm is significantly improved.

1. Introduction

Scale-invariant feature transformation (SIFT) [1] refers to the local features of an image, with rotation and scaling invariance and strong stability. The traditional SIFT algorithm has poor real-time performance and low matching accuracy. many experts and scholars have improved the SIFT algorithm, for example, Yan Ke introduced the PCA-SIFT algorithm[2] in 2004, which improved the matching speed, but the matching effect was unstable. Goushen Yu proposed a full affine invariant feature extraction algorithm ASIFT (Affine SIFT) [3], which achieved the robustness of affine invariance and viewing angle variation. However, low computational efficiency results in a limited range of applications. Although the above method effectively improves the SIFT algorithm, it still has time-consuming problem. Therefore, this paper proposes a SIFT matching algorithm in view of improved SUSAN operator and affine transformation.

2. Improved SIFT matching algorithm

This paper proposes a scoping algorithm in view of the improved SUSAN operator to extract feature points and based on affine transformation invariance.

2.1. Improved SUSAN operator

The SUSAN operator [4] traverses the image with a circular template, and the circle has rotation invariance, so this article selects operators to describe feature points. The size of the $M \times N$ image is



set, and the gray level of the pixel point (m, n) is $I(m, n)$. Where $m = 0, 1, 2, \dots, M-1$, $n = 0, 1, 2, \dots, N-1$. Traverse image I, comparing each pixel in the template with the center pixel:

$$c(r, r_0) = \begin{cases} 1, & |I(r) - I(r_0)| \leq t; \\ 0, & |I(r) - I(r_0)| > t; \end{cases} \quad (1)$$

Where $I(r)$ is the center pixel, $I(r_0)$ is the other pixels in the mask, t is a pixel difference threshold. By counting the value of $c(r, r_0)$, the size of the Univalence Segment Assimilating Nucleus (USAN) is obtained. The statistical method is:

$$n(r_0) = \sum_r c(r, r_0) \quad (2)$$

Among them, $n(r_0)$ represents the size of the USAN. The feature point is judged to be retained by calculating the center of gravity of the USAN area and the distance between the center of gravity and the center of the template. If the distance is small and the pixel passing through the center of gravity of the USAN area and the center of the template does not belong to the pixel of the USAN area, it is rejected.

The initial edge response is obtained by threshold processing:

$$R(r_0) = \begin{cases} g - n(r_0), & n(r_0) < g; \\ 0, & \text{others}; \end{cases} \quad (3)$$

Among them, $g = 3n_{\max}/4$, the USAN value is proportional to the response of the edge, then the point r_0 that satisfies the requirement of equation (4) is the corner point of the image:

$$g_1 < R(r_0) < g_2 \quad (4)$$

Among them, g_1 、 g_2 is the lower and upper limits of $R(r_0)$. When $R(r_0)$ is larger than g_1 , the image is smoothed by using Gabor filter, and the position and direction resolution of the feature point and noise robustness are improved due to the existence of isolated noise points [5]; Generally, the $R(r_0)$ of the isolated noise point is higher than the corner point, and the directional derivative of each feature point is obtained by traversing the image, and the isolated noise point is filtered by the upper limit g_2 to avoid interference of the corner point detection.

Extracting the corner points of the original image I using equations (3) and (4), Set the gray value of the corner point to 255, and set the other points to 0 to form the corner image S:

$$S(m, n) = \begin{cases} 255, & I(m, n) \text{ is a corner point;} \\ 0, & I(m, n) \text{ is a non-corner point;} \end{cases} \quad (5)$$

Because the SUSAN algorithm is simple, robust and not affected by the size of the template, the improved SUSAN algorithm is used to judge the feature points one by one and optimize the feature points.

2.2. Affine transformation

The affine transform [6] is a simple transform that includes rotation, translation and expansion. Let the coordinates of the P point in the original coordinate system be (X_{sp}, Y_{sp}) , and based on the origin rotation operation, a dotted line centered at (X_{s0}, Y_{s0}) is obtained horizontally perpendicular to the coordinate system. Based on the above discussion, the X and Y coordinates of P in the new

coordinate system are determined by the solid geometry:

$$\begin{cases} X = Y_{sp}\sin\theta_y + X_{sp}\cos\theta_x \\ Y = Y_{sp}\cos\theta_y - X_{sp}\sin\theta_x \end{cases} \quad (6)$$

Equation (6) can be converted to:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta_x & \sin\theta_y \\ -\sin\theta_x & \cos\theta_y \end{bmatrix} \begin{bmatrix} X_{sp} \\ Y_{sp} \end{bmatrix} \quad (7)$$

After the rotation transformation, the sum of the position of the P point in the new coordinate system and the offset between the X axis and the Y axis is determined, and the translation transformation is obtained, as shown in the formula (8):

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta_x & \sin\theta_y \\ -\sin\theta_x & \cos\theta_y \end{bmatrix} \begin{bmatrix} X_{sp} \\ Y_{sp} \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix} \quad (8)$$

The matrix of the affine transformation is a transformation matrix in the form of homogeneous coordinates:

$$\begin{bmatrix} \cos\theta & \sin\theta & t_x \\ -\sin\theta & \cos\theta & t_y \\ 0 & 0 & 1 \end{bmatrix} \quad (9)$$

The image is subjected to a certain degree of correction and mismatching point culling by affine transformation for identification and registration.

3. Analysis of experimental results

The computer CPU used to process images is Intel(R) Core(TM)i5 with a clock speed of 2.5GHz, a memory of 8.0GB, an operating system of Win10, and Matlab software version of R2014b. Comparative the improved algorithm, traditional SIFT algorithm and literature [7] algorithm, and feasibility analysis of the improved algorithm is carried out. The three sets of images shown in the table are matched by the above three algorithms, and the matching results are shown in figures 1, 2 and 3. The three sets of images are matched under different algorithms to match the logarithm, time and accuracy, as shown in Table 3.



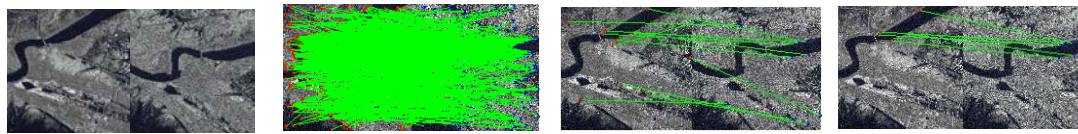
(a) left and right image (b) SIFT algorithm (c) literature [7] algorithm (d) this paper

Figure 1. Test image 1 matching result



(a) left and right image (b) SIFT algorithm (c) literature [7] algorithm (d) this paper

Figure 2. Test image 2 matching result



(a) left and right image (b) SIFT algorithm (c) literature [7] algorithm (d) this paper

Figure 3. Test image 3 matching result

Table 1. Image Size

Test group	Left image size/pixel	Right image size/pixel
test 1	401*403	401*403
test 2	600*450	600*450
test 3	400*400	400*400

Table 2. Statistics of experimental data

Algorithm	Match result	test 1	test 2	test 3
SIFT	Points/pair	958	238	3506
	Accuracy/%	96.39	89.64	98.8
	Time/s	7.564	4.047	24.079
Literature[7]	Points/pair	15	10	11
	Accuracy/%	96.5	90.46	97.7
	Time/s	1.786	0.607	1.052
This paper	Points/pair	6	5	5
	Accuracy/%	97.36	96.32	97.5
	Time/s	0.425	0.314	0.306

Comparing the matching algorithms, matching precision and matching time of the above three algorithms, it can be seen that the SIFT image matching algorithm has better matching results, but the algorithm itself is more complicated and the calculation time is longer. Feature point matching in literature [7] is to eliminate unmatched feature points by adding constraints, which improves algorithm efficiency and matching accuracy. Based on the research of classical image matching algorithm, the improved SUSAN algorithm is used to extract feature points by adding constraints, and the affine transformation is used to eliminate mismatched points and improve the accuracy of matching points; At the same time, the image fusion area is weighted and averaged to achieve the effect of smooth image display, and finally the image is spliced. Through the above experiments, it is proved that the algorithm effectively shortens the matching time to a certain extent and improves the matching precision.

4. Conclusion

Based on the analysis of SIFT image matching algorithm, SIFT algorithm matching algorithm in view of improved SUSAN operator and affine transformation is proposed. Experiments show that this method can shorten the detection time and improve the matching efficiency.

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