Research of Image Matching Based on Improved SURF Algorithm

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Abstract

In the study, it presents an efficient algorithm based on SURF (Speeded Up Robust Features). The method applies the SURF algorithm in the detection and description for image features, first it applies the SURF feature detector in extracting reference images and matching feature points in the image, respectively, then it uses DAISY algorithm instead of the SURF algorithm to calculate the character description of each feature point vector. In the process of feature points matching, the false matching points are eliminated through RANSAC algorithm. Finally, according to the rest of the match point, it can estimate the space geometric transformation parameters between two images and thus matching process is completed.

Keywords: SURF algorithm, feature points, image matching, research, simulation

1. Introduction

At present, the image matching methods can be roughly divided into two classes; one is the image matching based on image matching and feature matching [1]. Matching method is directly use the image grey value to determine the space geometry transform between the images, this method can make full use of the information of the image, so it is also known as the matching method based on integral image content, it has no feature detection steps, in the feature matching stage, the fixed size window and even whole image matching are adopted in estimation, so the calculation is simple and also easy to be performed.

High contrast in the regional characteristics has a wide range of applications in image matching, such as reservoirs, lakes and forest, buildings, etc. Regional characteristics often is tested by using the method of image segmentation, so the accuracy of image segmentation can directly influence the results of matching, Dai [2] applied the invariant moment method to describe the area of picture, and used the Euclidean distance as the similarity measure criteria, Goshtasby [3] used iterative methods to get better performance on image segmentation, and got subpixel level accuracy of the image matching; and took the center gravity point of region as the key point to carry out image matching; And Ton [4] took the center of mass in the flake areas as a key point in image matching. In the image matching based on outline, the first step is to extract the contour feature in the image, and then geometric transformation is obtained through the contour matching between images.

Li, etc. [5] applied image contour feature in the matching, and matching is realized between the different sensor images; Tham [6] expressed the outline of features with the chain codes, and realized matching indirectly through chain code of the contour; Yuan [7] put the method of pyramid strategy in contour matching. Image edge refers that the gray level of the image is changed dramatically in one direction, while the gray level in the direction perpendicular to this direction is changed slowly; it is a kind of important structural features in the image. Many scholars have put forward all kinds of edge detection method,

Ziou etc. [8] made detailed comparison and summary on the image edge detection method. In certain circumstances, the use of edge feature in image matching can achieve very good effect. [9] extract edge points as image feature points, and adopted the most similarity measure of the Hausdorff distance criteria in the process of feature matching. Yanken used PCA (Principal Components Analysis, PCA) - SIFT method in the data dimension reduction of character description, however, the amount of calculation is not reduced, and the feature point

extraction part of the method is not improved. Bay, etc. [10] an algorithm called SURF, it is the improved SIFT algorithm, the algorithm of SURF and GLOH (Gradient Locationand Orientation Histogram and GLOH), SIFT, and PCA-SIFT are all compared, the results showed that SURF are close to or exceed SIFT in all aspects of performance, and the computing speed is about three times of SIFT; Rong [11] adopted the SURF algorithm and the nearest neighbor matching strategy in different types of image matching process and they achieved the good effects. Hartley R [12] added the search strategy of BBF (Best-Bin-First, BBF) in SURF algorithm, and the speed of matching feature points is improved.

2. Surf Algorithm
2.1. Detection Operator of the DoH Feature

Similar to SIFT algorithm, feature points detection part of the SURF algorithm is also based on scale space theory. The difference is that SURF algorithm is mainly applied to the DoH (Determinant of Hessian), the extraction of the feature points in the image are realized through simplification and approximation, compared to the SIFT algorithm, it reduces the complexity of feature point extraction and it also has better real-time performance.

Take the one point $X = (x, y)$ in the picture as example, in the scale of σ its Hessian matrix is defined as:

$$H = \begin{bmatrix} L_{xx}(X,\sigma), L_{xy}(X,\sigma) \\ L_{yx}(X,\sigma), L_{yy}(X,\sigma) \end{bmatrix} \tag{1}$$

Among them: $L_{xx}(X,\sigma)$ is the scale σ for the Gaussian second order differential $\frac{\partial^2}{\partial x^2} g(\sigma)$ and the $I(x, y)$ convolution results at point X:

$$L_{xx}(X,\sigma) = \frac{\partial^2}{\partial x^2} g(\sigma) \otimes I(x, y) \tag{2}$$

Among them, $g(\sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$ and $\otimes$ represents the two-dimensional convolution operation, the meaning of $L_{xy}(X,\sigma)$ and $L_{yy}(X,\sigma)$ are similar. DoH, the determinant of H is as type (3).

$$Det(H) = \sigma^4 (L_{xx}(x, y, \sigma) L_{yy}(x, y, \sigma) - L_{xy}^2(x, y, \sigma)) \tag{3}$$

(a) The DoH response value maximum 50 points   (b) The DoH response value maximum of 300 points

Figure 1. Feature Points of the DoH Test Image

Then after searching the local extreme value of DoH through Image scale space and the location space after the response of method,it can complete the feature point detection; this is the principle of the DoH algorithm. In the Figure 1, the result of the feature points in an image through using of the DoH algorithms is presented. Scale range of σ is 2 ~ 15, step length is 1, so the total scale is 14. Figure 1(a) is the result of DoH response value with maximum 60 points, and Figure 1(b) is one with the maximum 500 points, the DoH response values and the number of feature points extraction can be changed by adjusting the response threshold value.

In Figure 1, the DoH test image feature point, It is easy to find that this kind of method can be used to suppress noise interference, because the scale of the noise are small, so the response value of DoH also is small, if the response threshold value is set as big as possible, then extraction mistake of image feature can be avoided.

2.2 Detection Operator of the DoH Feature

In the process of feature points detection of the SURF algorithm, the Integral Image (Integral Image) and the filter Box (Box filters) are adopted, is one of the characteristics of the DoH test operator approximation. It used box filtering method to replace the second order Gaussian differential, so the template filter only needs a few of the images addition and subtraction, and it has nothing to do with the size of the filter. In addition, in the SURF algorithm, it also uses the integral image to accelerate the process of convolution computation, and it can greatly improve the speed of the whole operation process. Select second order differential Gaussian when $\sigma = 1.2$, respectively use Dxx, Dyy and Dxy to the represent the convolution value of the template image.

Figure 2 is a picture of the original image (the size is 480*480), and its corresponding integral image (it needs to points out that the picture image grey value reflect is not the real value, is only to show that needs to be grey degree level changes to 0 ~ 255, the actual value is much larger). It can be seen that the integral image grey value from the upper to left corner gradually accumulate along the diagonal direction.
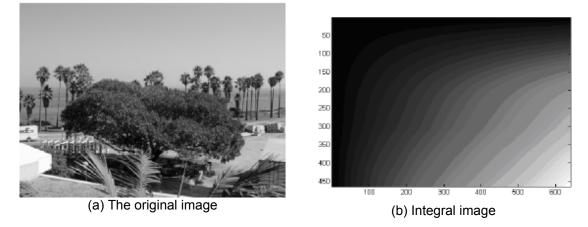

(a) The original image

(b) Integral image

Figure 2. Integral Image and the Original Image

The Hessian matrix determinant can be simplified to:

$$Det(H)=Dxx \quad Dxy-(0.9Dxy)2 \tag{4}$$

Different template size and value can make Det(H) value is different, but simplicity, type (4) is the unified formula, this does not affect the unified formula and this does not affect the testing results of the subsequent maximum. It adopts the approximate Hessian matrix to represent the image of a point response value and formed the image of feature point detecting under a certain scale.

2.3. DAISY Description Operator

DAISY character description operator is proposed by Tola et al. [13, 14]; Tola et al, 2010), it is the new image of local characteristics describes the operator. The algorithm for the affine transformation and illumination differences between images has a better robustness, and has great advantages in describing the operator time. When the number of feature points is large, it can be a very good in solving the problem of description operator, so it is often used in the process of dense matching of stereo vision, etc.

(1) Convolution direction map

The core idea of DAISY algorithm is that it does not adopt the weighted gradient image like SIFT algorithm, while it adopts the method of directional derivative convolution, make the original image with a number of Gaussian filtering functions which not only can keep the close to performance of SIFT, but also its computing speed is very fast.

Before describe DAISY principle, the first step is to point out that the concept of pattern, for any of the input image Like I, define a specific direction the direction of the o the graph is (5):

$$G_o = (\frac{\partial I}{\partial o})^+$$

(5)

Where (a)+ =max(a,0), It can calculate N direction image accordance with the above method : $G_i = i \le i \le N$.

Then use the direction figures with a series of Gaussian function with different convolution kernels and do convolution, thus different convolution pattern will be generated.

(2) Generation of DAISY describe the operator

Take any one point in the image (u, v) as the center, in its neighborhood is within the radius $\{R_1, R_2, ...R_M\}$ respectively, and generate the M layer sampling points the center of which is (u, v) as in circle, character description operators of the DAISY algorithm are made by these sampling points generated by the convolution of pattern vectors. It does not like SIFT algorithm adopt rectangular neighborhood, because the circular neighborhood has better positioning properties than rectangular neighborhood. The application of the Circular neighborhood and Gaussian function with the high isotropic Nuclear at the same time, make character description operator of DAISY have certain robustness with changing of the rotation of the image.

3. Consistency Random Sampling Alogorithm

Projection transformation is the description of observable situation from any viewpoint in limited distance, when there is no imaging distortion; it is a common transformation of image space, the general form of the projection transformation matrix of the eight parameters, can be represented as below:

$$M = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

(6)

$$x^{'} = \frac{a_{11}x + a_{12}y + a_{13}}{a_{31}x + a_{32}y + 1}$$

(7)

$$y^{'} = \frac{a_{21}x + a_{22}y + a_{23}}{a_{31}x + a_{32}y + 1}$$

(8)

From the types above, the calculation of image renovation needs to work out at least eight parameters, and at least eight equations in theory are needed, so it needs at least 4 non-collinear feature points. False matching points will influence the result of the least squares

estimates. Before the estimation of space geometry transform parameter, it can be purified through certain methods. Random sampling of consistency (RANSAC) algorithm is based on the characteristics of the stamp matching process of the classical algorithm.

RANSAC algorithm steps:

1) From the equation of matching feature points are selected, randomly selected from 4 points to set up equations, solve the eight unknown parameters of the transformation matrix M.

2) Calculate rest of the feature points after a transformation matrix M transformation, and calculate the distance between candidate matching points.

3) If the distance is less than a certain value, the candidate point is looked as interior point or the outside point.

4) Make the statistics of the quantity of interior point under the transformation matrix.

5) Choose another four match points, carry out steps 1 to 4 again, and repeat several times, choose the collection with largest number of interior points.

4. Simulation Experiment and Result Analysis

Through the analysis of algorithms and simulation experiment, the experiment, simulation platform hardware environment is the Intel Pentium dual-core CPU, 4GB ram, software development tools for Windows 7 operating system, the MATLAB R2011b, VC++6.0. The experiment images are from the visual research laboratory at the Nanjing University.

First, the experiments are performed to verify the method of operator generated in time described in the study compared with the advantage of the SURF. The SURF-DAISY algorithm presented in this study, and SURF algorithm described in the paper [15] are adopted in test of image feature point detection and the comparison experiment are performed.

It can be seen from Table 1 and Table 2 that DAISY algorithm in the feature description operators do have big advantage, in the generation time of four test image in Figure 2, DAISY description operator generated time is about 47.6% of standard SURF operator generated time. This is because in the process of the DAISY description operator, the gradient histogram statistics method is not adopted compared to SURF and SIFT, so quite a lot of consumption time is saved. Next to verify on the premise of guarantee the registration accuracy, it adopts related methods in the whole registration algorithm is relative to the present speed improvements. The method in paper [11], are respectively adopted in this article, in the Figure 4, the image feature points matching accuracy and time statistical comparison of two groups are made, because both methods adopt the RANSAC, make the comparison of the two algorithms is to get better the performance of the feature matching stage, and the matching accuracy is calculated before using RANSAC.

Table 1. Statistics Time of Feature Point Detection and Description Based on SURF-DAIS Algorithm

	Number of feature points	Inspection time /S	Describe the operator generated time /S	The total time /S
(a)	1487	2.12	2.89	5.01
(b)	1352	2.25	2.75	5
(c)	455	1.02	1.28	2.3
(d)	489	1.12	1.32	2.44

Table 2. Statistical Time of Point Detection and Description Based on SURF Algorithm

	Number of feature points	Inspection time /S	Describe the operator generated time /S	The total time /S
(a)	1487	2.32	5.31	7.01
(b)	1352	2.24	4.90	7.14
(c)	455	1.02	2.80	3.82
(d)	489	1.12	2.71	3.83

Among the figures are different sizes the size is 386 x 306 and 472 x 335 respectively; the using of two methods for feature point matching accuracy and time of the statistical results are listed in Table 1 and Table 2.

(a)   (b)

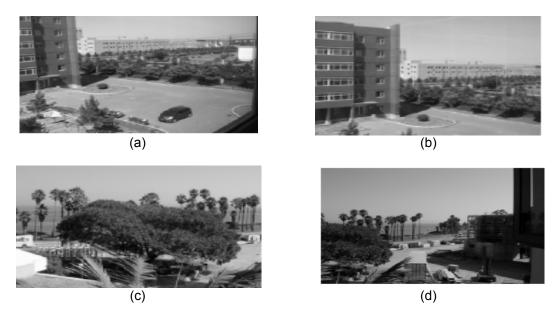(c)   (d)

Figure 4. The Test Images with Unknown Transformation Parameters

It can see from although the test images between different viewpoints, size different, the difference of rotation Angle, the light changes or different sensors, etc. Various kinds of differences, the method can detect the feature points in abundance and high repetition rate, all these are attributed to SURF feature detector for rotation, scale and illumination changes, such as robustness; Compare with the image matching method in literature (Bracewell, 1965), in this study, the methods is to keep the matching accuracy, and at the same time, increase the speed of the algorithm, which is attributed to high speed and stable performance of the DAISY description algorithm.
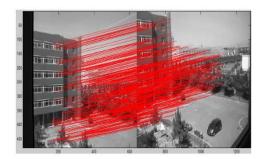

Figure 6. Matching Process of Image (a) (b) of Figure 5

Figure 7. Matching Result of Image (a) (b) of Fig.5

Figure 8. Matching Process of the Image (c) (d) of Figure 5

Figure 9. Matching Result of the Image (c) (d) of Figure 5

Table 3. The Parameters of Registration Results

Method	Matching success rate	RMSE	Registration time
Method in the study	88.5	0.45	8.79
Method in paper (Mount et al,1999)	87.3	0.48	17.45

Figure 6 to Figure 9 are the results of the image feature matching and matching of each image, it can be seen that matching images between different viewpoints, gray scale change, the difference of angles, under different light conditions, and so on, the algorithm also can obtain very high matching accuracy, the implementation of the registration between two images can be completed.

Table 3 is to choose the (a)-(d) in Figure 4, and make the comparison of registration quantitative results, on the premise of guarantee the registration success rate, this article and methods in literature(Rong et al,2009) recompared, the reduced time consumption of whole registration process is about 45.6 %.

The results are due to the more efficient SURF-DAISY algorithm it adopted, it not only played a SURF feature detector in rotation, scale and illumination changes such as robustness, but also played a DAISY in the description of the operator to generate time advantage, from each director; Secondly, in the feature matching stage, this article does not adopt the method of literature (Rong et al, 2009), the experimental results show that the algorithm accuracy is close to exhaustive search, while the speed is much faster than the exhaustive search again.

5.Conclusion

This study puts forward an algorithm based on SURF-DASIY algorithm of image matching methods. This method first uses standard SURF algorithm in the feature point extraction method. It is used in the reference image and stay registration, then it adopts the DAISY describing vector. From the experiments, it can be found the algorithm can effectively improves the speed of the generated description operator, the DAISY description operator generated time is about 47.6%, of standard SURF algorithm, so it can present full express to the robustness of SURF feature detectors and the efficiency of DAISY algorithm.

Description for DAISY operator dimension is high thus leads to the problem of long matching time, it adopt the RANSAC algorithm to eliminate false matching point. Finally it estimates the space geometric transformation parameters between two images and completes the matching according to the rest of the matching point. When it keeps the matching success rate under the premise of the method in the whole process, it can reduce time consumption about 45.6%.Experiments show that this algorithm is the registration method with fast and robust ability.

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