

# Image Registration Based on Corner Detection And Affine Transformation

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**Abstract**—Image registration is an important part of the image processing and computer vision. On the basis of analyzing two types of image registration, an automated image registration method was put forward to dealing with image registration with similar transformation. At first, Corner feature was extracted by the improved multi-scale Harris operator, next, the image edge detection was conducted by canny operator, corner's coarse matching may be realized based on correlation coefficient between the corner neighborhood on the edge image, and then fine matching can be achieved, two pairs of optimal matching corner were selected from matched corners as control points of affine transformation, thus, affine transformation model could be obtained, and the registered image was performed affine transformation in order to realizing image registration. Theoretically speaking, this method's advantage isn't subjected to change limitation of the displacement, rotation and scale between two images. Finally, the simulation experiment was performed to verify and analyze the algorithm characteristics; the results show that the automatic registration algorithm is correct and effective.

**Keywords**- corner detection; improved Harris operator; edge detection by Canny operator; affine transformation; automatic image registration

## I. INTRODUCTION

At present, image registration has been carried out a lot of research work, a variety of image registration methods were put forward, which were usually divided into two categories: region-based methods and feature-based methods. The former adopts correlation technique to determine corresponding matching position between two images. it is easy to implement, but large amount of calculation is serious problem, especially, due to rotation, scaling and shifting transformation influence and distortion such as shading, degradation of images, the algorithm effectiveness will be dropped dramatically; the latter firstly extracts some common invariant features, such as contour, moments, etc., next, fine matching is conducted, because of invariant features, nothing to do with the image gray level, the ambiguity of registration can be effectively solved. among various invariant features in the image, the corner has the merits of the rotation invariance and almost immunity to illumination conditions, so feature-based method has been widely used. In order to solving the rotation and shifting transformation relations, in this paper, a new image registration algorithm based on the corner detection and affine

transformation model is brought forward. Firstly, corner points are extracted by using multi-scale Harris operator from two images, next, edge images can be obtained by Canny operator, and then, corner points matching is implemented by using the correlation between the edge images to determine homologous corner point, subsequently, the affine transformation model between the image pairs is established, through calculating model parameters, accordingly image registration can be accomplished. Finally, the simulation experiment is done to verify and analyze the new algorithm.<sup>[1][2]</sup>

## II. CORNER DETECTION BY MULTI-SCALE HARRIS OPERATOR

The commonly used automatic point feature extraction algorithms include: the method based on wavelet transform, SUSAN operator, Harris operator, Forstner operator, Morave operator and so on. Harris operator has been proved to be one of the best corner detection operators<sup>[3]</sup>.

Harris operator was put forward by C. Harris and M. J. Stephens in 1988, which extracted point feature by the first order image gradient. The method calculates square matrix of the average gradient of each pixel, and then feature points can be extracted by analyzing eigenvalue. Experiment shows that feature points by this method distribute evenly and reasonably, may extract feature points quantitatively. Inadequately, the algorithm is only a single scale corner detection, the result relies entirely on the threshold value setting, if the threshold value is large, it result in corner missing, if smaller threshold, also easily mixed with false corner<sup>[4]</sup>.

Multi-scale space representation of the image obtained by smoothing can be described as  $(x, \sigma)$  space, here,  $x$  and  $\sigma$  is location parameters and the scale parameter respective. When the same images are filtered by using smoothing function of different scales, the result images are a cluster of scale space the original image relative to the smooth function,  $\sigma$  is the scale-space coordinates. In this paper, corner operator is transformed into expression of scale space by the first order derivative of Gaussian kernel  $G(x, \sigma) = \frac{1}{\sqrt{2\pi}\sigma} \exp[-x^2/(2\sigma^2)]$ . Multi-scale Harris corner

detection operator is put forward, which transforms image into different scale space, with the advantage of integrating small-

scale precision positioning points with large-scale eliminating the false points and retaining the true points. Specific steps of multi-scale Harris corner detection are as follows [5] :

a) The scale space expression of Harris operator. The corner measurement of different scales and scale change are in accordance with the standard deviation  $\sigma_i = 0.5:5$  of the Gaussian window, step length is 0.5, namely  $i = 1:10$ , the calculation of the following formula forms the matrix  $M$  of different scales:

$$I_x^2(\sigma_i) = G(\sigma_i) \otimes \left(\frac{\partial I}{\partial x}\right)^2 \quad (1)$$

$$I_y^2(\sigma_i) = G(\sigma_i) \otimes \left(\frac{\partial I}{\partial y}\right)^2 \quad (2)$$

$$I_{xy}(\sigma_i) = G(\sigma_i) \otimes \left(\frac{\partial I}{\partial x} \cdot \frac{\partial I}{\partial y}\right) \quad (3)$$

$$M(\sigma_i) = \begin{bmatrix} I_x^2(\sigma_i) & I_{xy}(\sigma_i) \\ I_{xy}(\sigma_i) & I_y^2(\sigma_i) \end{bmatrix} \quad (4)$$

Where,  $\frac{\partial I}{\partial x}$  is the first derivative in the  $x$  direction,  $\frac{\partial I}{\partial y}$

is the first order derivative in the  $y$  direction,  $G(\sigma)$  is Gaussian function,  $M(\sigma_i)$  is matrix  $M$  in the scale  $\sigma_i$ . Corner response function is calculated in the scale  $\sigma_i$ :  $R(\sigma_i) = \det(M(\sigma_i)) - 0.04 * (\text{trace}(M(\sigma_i)))^2$  (5)

b) For each scale, the response points of local maximum are obtained by using non-maxima suppression method in the same window of Gaussian kernel size. The former  $C_{num}$  is selected as candidate corner according to descending order. ( $C_{num}$  Indicates the reference value of feature point number, ranging from  $0.5 D_{num}$  to  $2 D_{num}$ .  $D_{num}$  is the sum of image length and width. In this paper, the number of  $C_{num} = D_{num}/10$  integers replaces the threshold  $T$  in various scales. In this way, the threshold value needn't manually been adjusted in each scale, the number of corner points needn't human intervention).

c) The minimum scale point is selected as the final point in the same window of Gaussian kernel size. If the minimum scale point is only included in the window, the point is deleted. Thus the point can be ensured to achieve in the scale as small as possible, the positioning accuracy is further improved, the information point in large scale is still retained, meanwhile, deleting false corner in small scale.

d) Sub-pixel accurate positioning of point. The process can be accomplished by Taylor expansion of space scale function  $D(x, y, \sigma)$  in the local extreme point  $(x_0, y_0, \sigma)$ .

The multi-scale Harris corner detection method can acquire corner information in a number of scales, corner quantity is reasonable, the threshold in each scale needn't be manually set, thus, reducing the threshold constraints on the corner detection, realizing corner accurate positioning in the small scale and ensuring the false corner eliminated and the true corner retained in the large scale.

### III. CANNY EDGE DETECTION ALGORITHM

Before pixel gray between the reference image and matched image has weak correlation, the edge images have strong correlation. Thus, corner matching can be realized in the edge maps, subsequently, image registration is accomplished. The traditional edge detection method is sensitive to noise, so the application is not effective. In recent years, more and more new technologies are introduced to the edge detection, such as mathematical morphology method, wavelet transform methods, the neural network and fractal methods. Canny edge detection algorithm based on the optimization theory has been extensively used with the advantages of large signal to noise ratio, high detection accuracy and low computation [6].

Canny edge detection operator has the following three rules: signal to noise ratio rule; positioning accuracy rule; single edge response rule. Based on three rules, the optimal edge detection operator can be formed. Canny edge detection algorithm is as follows:

- a) Smoothing image with Gaussian filter;
- b) Calculating the gradient magnitude and direction by the finite difference of the first-order partial derivatives;
- c) Non-maxima suppression for amplitude of the gradient;
- d) Detecting and connecting the edge by double threshold algorithm.

### IV. CORNER MATCHING AND CONTROL POINT SELECTION

After Corner matching may be implemented by the edge correlation on edge images. At first, coarse matching is carried out in large scale neighborhood. assuming corners1 and corners2 store separately corner coordinate detected from reference image and registered image, with regard to each corner of corners1 and corners2, a corner-centered template  $k \times k$  ( $k$  is odd number) is established respectively, next, correlation operation between the template related to a corner selected in corner2 and the corresponding template in corner1 is performed, Setting a threshold  $T'$ , when the correlation operation result is  $\text{corners1} > T'$ , corner matching is successful, getting a pair of match points [7].

After this step, a new two corner newcorners1 and newcorners2 is obtained, among them, corner is matched one by one, namely, newcorners1  $[i]$  and newcorners2  $[i]$  ( $i = 0, 1, 2 \dots n$ ) is corner matching pair,  $n$  is the total number of corner matching.

Next, fine matching in small neighborhood is conducted, and selecting the control points. The specific step is: according to previous method, a corner-centered template  $k' \times k'$  ( $k'$  is odd number and  $k' < k$ ) is established respectively in newcorners1 and newcorners2, next, calculating the correlation coefficient for a pair of template, finally, two pairs of matching corners of the largest correlation coefficient are selected as control points.

## V. AFFINE TRANSFORMATION MODEL CALCULATION AND INTERPOLATION

Formula (6) is the general form of two-dimensional affine transformation. Where,  $(x', y')$  and  $(x, y)$  are the two images pixel coordinates respectively. It is obvious that there are four unknowns in the model, as long as the coordinates of four points  $(v1(x'_1, y'_1), v2(x'_2, y'_2), i1(x_1, y_1), i2(x_2, y_2))$  is known, these parameters can be calculated. Here,  $v1, v2$  is the point of the reference image,  $i1, i2$  is the point of the registered image, formula (7) is the expansion expression of formula (6),

$$\begin{cases} s = \frac{x'_2 - x'_1}{\cos(a) \cdot (x_2 - x_1) - \sin(a) \cdot (y_2 - y_1)} \\ a = \arctan\left[\frac{(x_2 - x_1) \cdot (y'_2 - y'_1) - (x'_2 - x'_1) \cdot (y_2 - y_1)}{(y_2 - y_1)(y'_2 - y'_1) + (x'_2 - x'_1)(x_2 - x_1)}\right] \\ \Delta x = x'_1 - s \cdot (\cos(a) \cdot x_1 - \sin(a) \cdot y_1) \\ \Delta y = y'_1 - s \cdot (\sin(a) \cdot x_1 + \cos(a) \cdot y_1) \end{cases} \quad (8)$$

The affine transformation parameters can be calculated by coordinates of control points, and then, geometric transformation may be conducted for registered image; finally, image registration is accomplished. in the process of image geometric transformation, because transformed coordinate is not an integer, or no mapping point exists between the target image and the original image, the color values of these points can be obtained by interpolation. Common interpolation methods include: nearest neighbor interpolation, bilinear interpolation and bicubic interpolation. Computational complexity and interpolation effect are taken into account, so the simulation experiment adopts bilinear interpolation.

## VI. SIMULATION AND ANALYSIS

The whole experiment realizes the above proposed algorithm by using Matlab7.0 and VC++6.0 on PC, due to a lot of the same or different types of sensor images with greater mismatch, two experiments are implemented. Experiment one carries out automatic image registration by two images of the same area under different imaging condition, shown in Fig.(1). the reference image is orthophoto Fig.(a), registered image is aerial photo Fig. (b). Fig. (C) and Fig. (d) are corner detection map of Fig. (a) and Fig.(b) respectively based on multiscale harris operator. Next, histogram matching is performed to improve image quality, increasing the similarity of different images, so as to extract more homologous points. Fig (e) and

thus the four parameters  $(s, a, \Delta x, \Delta y)$  can be solved through formula (8) [8] [9].

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = s \cdot \begin{bmatrix} \cos(a) & -\sin(a) & 0 \\ \sin(a) & \cos(a) & 0 \end{bmatrix} \cdot \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} + \begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} \quad (6)$$

$$\begin{cases} x'_1 = s \cdot (\cos(a) \cdot x_1 - \sin(a) \cdot y_1) + \Delta x \\ y'_1 = s \cdot (\sin(a) \cdot x_1 + \cos(a) \cdot y_1) + \Delta y \\ x'_2 = s \cdot (\cos(a) \cdot x_2 - \sin(a) \cdot y_2) + \Delta x \\ y'_2 = s \cdot (\sin(a) \cdot x_2 + \cos(a) \cdot y_2) + \Delta y \end{cases} \quad (7)$$

Fig. (f) are the corner detection map after histogram matching, Fig(g) presents coarse matching map, Fig(h) is fine matching map, Fig.(i) shows the image after registration, Fig.(j) shows the overlay effect map; Experiment two makes automatic image registration for the same region of different sensors, shown in Fig. (2), the reference image well registered with the ground image is SPOT-V panchromatic image, shown in Fig. (k), registered image is TM multi-spectral image of the corresponding region, shown in Fig. (l), Fig. (m) is overlay display map after automatic registration between two image. The existing point-based registration method commonly uses root mean square error (RMSE) to evaluate the quality of image registration; the paper also adopts this method [10], shown in table 1.

$$\begin{aligned} dx(i) &= x'_i - sx_i \cos a + sy_i \sin a - \Delta x \\ dy(i) &= y'_i - sx_i \sin a - sy_i \cos a - \Delta y \\ RMSE &= \sqrt{\sum_{i=1}^K dx^2 + dy^2} / K \end{aligned} \quad (9)$$

Where,  $K$  is the number of matched corner,  $dx, dy$  are  $x, y$  difference value between transformed point according to parameters and its matching point,  $s, a, \Delta x, \Delta y$  is the four parameters of affine transformation.





Fig. (a) Reference image



Fig. (b) Registered image



Fig. (c) Corner detection map based on multi-scale Harris operator for Fig.(a)



Fig. (d) Corner detection map based on multi-scale Harris operator for Fig.(b)

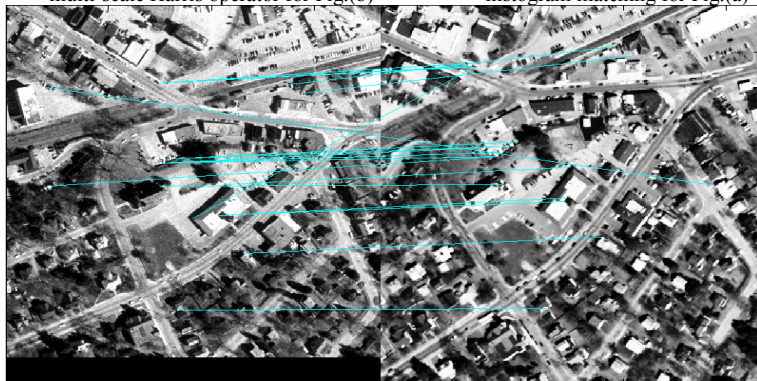


Fig. (e). Corner detection map after histogram matching for Fig.(a)

Fig. (f).corner detection map after histogram matching for Fig.(b)



Fig. (g). Coarse matching map



Fig.(i) Image after registration



Fig. (h) Fine matching map

Fig. (l) Aerial image automated registration based on multi-scale Harris operator and affine transformation

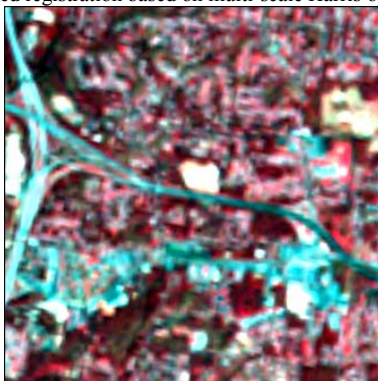


Fig.(j) Overlay display map

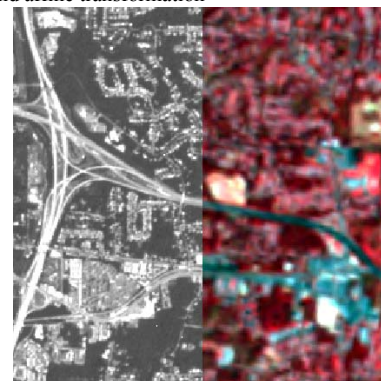


Fig. (k) Reference image

Fig. (l).Registered image

Fig. (m).Overlay display map

Fig. (2) Automated registration between SPOT-V image and TM image based on multi-scale Harris operator and affine transformation

TABLE I. INDEX VALUE OF EXPERIMENT 1 AND 2

index number	$a$	$s$	$\Delta x$	$\Delta y$	RMSE
one	10.54	1.123	20	22	0.5076
two	0	0.91	-13	-15	0.3222

## VII. CONCLUSION

The experimental results show that aerial images and satellite images achieve a very good automatic registration by adopting corner neighborhood correlation matching on the edge map and affine transformation. This method can achieve a better registration for two or more images which have the difference of rotating, scaling, shifting and different field of view. Compared with the traditional image registration methods, it is simple, low computational complexity; good real time no manual operation under optimal parameters conditions, stable and reliable. But control point selection for affine transformation is carried out on the edge map, if the edge Detection result is not satisfactory, it will affect the selection of control points, and image registration cannot be achieved then. Thus, in future studies, image registration should be committed to good edge detection algorithm and the automatic selection of various parameters optimization<sup>[11]</sup>.

## ACKNOWLEDGMENT

Supported by National High — Tech Research and development program (863) of china 2007AA12Z162) Nature Science Foundation of Digital Land Key Laboratory of Jiangxi Province (DLLJ201009), Nature Science Foundation of Xuzhou Normal University(08XLS03) and sponsored by Qing Lan Project

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