Registration algorithm of aerial remote sensing images based on lateral inhibition competition

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Abstract: Image registration is a key step in image mosaic, image fusion and object localization. Given the problem that the aerial remote sensing images may have the uncertainty in image gray level and may be lack of feature information, a registration algorithm of aerial remote sensing images based on lateral inhibition competition was proposed, Firstly, the bright feature points and dark feature points of the reference image and the under registration image were detected with the basic idea of lateral inhibition competition. Then, the similar nature feature points of two images were combined with feature matching strategy and the matching-points sets was shaped. At last, the image transform model was calculated and the images were registered. A new thinking was provided for image registration. Comparing with the traditional feature registration algorithm, the experimental results show that the proposed algorithm has better registration, the aerial remote sensing images can be registered effective. Some conclusions are obtained through the analysis and explanation of the experimental data, which lay a solid foundation for further research.

Key words: image registration; lateral inhibition competition; feature points detection; feature matching

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基于侧抑制竞争的航空遥感影像配准算法

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摘 要： 图像配准是图像镶嵌、图像融合和目标定位等的核心技术。针对航空遥感影像中存在的特征信息匮乏以及不确定性灰度变化的问题，提出了一种基于侧抑制竞争的航空遥感影像配准算法，该方法利用侧抑制竞争的基本思想，首先检测出基准图像与待配准图像的暗特征点和亮特征点，然后利用特征匹配策略匹配两幅图像中同类性质的点特征，合并匹配点对集，最后计算出图像的变换模型，完成图像的配准工作。实验结果表明，该方法配准精度高、速度快，能够稳定并快速地完成可见光航空遥感影像的配准，解决了特征不明显的航空影像间配准成功率低的问题。

关键词： 图像配准； 侧抑制竞争； 特征点检测； 特征匹配

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0 Introduction

In process of aerial remote sensing camera image, due to different imaging conditions, there are great differences in visual angle, position, resolving power and gray between two or more images in the same scene. An optimal geometric transformation can be found in image registration, two or more images in the same scene can be aligned in space geometry, eliminate or reduce the differences between two or more images, and then the image with geometric consistency is obtained.

There are two main methods of image registration based on gray and feature. The method based on gray mainly includes the cross-correlation method[1], the maximum cross correlation method[2] and the mutual information method[3]. The method based on feature is mainly to extract and match the feature elements between two images, feature elements are mainly point features, line features and surface features[4]. The point features are mainly Moravec operator [5], Harris operator[6], SUSAN operator[7] and SIFT feature[8]. The line features are Edison feature[9] and LSD feature[10], etc. At present, the point feature is one of the most common and efficient methods.

The method of image registration based on feature rely on feature extraction precision, using features to build a whole transformation model, it often causes local deformation to be taken into consideration, especially the lack of feature information and uncertainty gray change in aerial remote sensing images, which bring some difficulties to feature detection. In this paper, a registration algorithm of aerial remote sensing images based on lateral inhibition competition is proposed. The method uses the basic idea of lateral inhibition competition, and detects the dark feature points and the bright feature points of the reference image and the registration image, and then uses the feature matching strategy to register, ensuring the accuracy of registration.

1 Algorithm overview

The registration algorithm of aerial remote sensing images based on lateral inhibition competition mainly includes four parts: feature points detection, feature description, feature matching, and calculating image transformation model. The realization process is illustrated in Fig.1. The bright feature points and dark feature points can be detected with the feature point detection algorithm based on lateral inhibition competition, and the unity of the feature points to describe the SIFT descriptor, and then use the feature matching strategy, two pieces of similar nature in the image feature points, with matching points set, and finally calculate the image transform model the complete image registration.

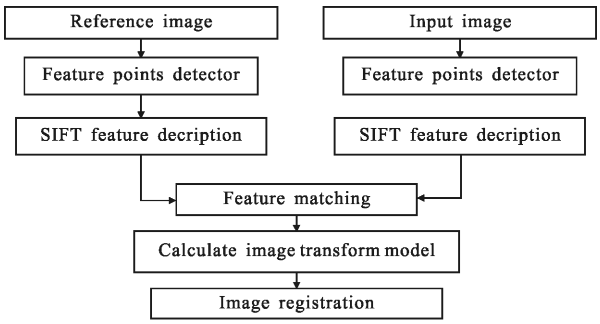


Fig.1 Flow of automatic registration algorithm of images based on maximum gradient phase correlation

2 Algorithm implementation

2.1 Feature point detection algorithm based on lateral inhibition competition

Lateral inhibition phenomenon[11] was first proposed by biologists, Hartline and others, after a long study of the visual system of Limulus. Lateral inhibition is mutual, but in the retinal image, the light is very bright feeling in the area of unit light inhibited dark receptors in the cell region exerted inhibitory effect on the former than the latter, so the inconsistency of these receptors in exacerbated, and the contrast enhancement.

For digital image, each pixel of the digital image as the input layer, establish the competitive layer and the corresponding input layer and the network connection in the output layer, each pixel and the pixels around it with lateral network connection and the network output by neurons in the mutual inhibition and competition in determining. According to the network connection degree and mode, the 3×3, 5×5 or other form of digital image side suppression competitive network model can be established. In this paper, a non-cyclic inhibition network model of 3×3 networks is used to study. After the digital image passes the lateral inhibition network, the pixel gray level[12]:

$$I(m,n)=f[\sum_{i=-1}^{1}\sum_{j=-1}^{1}a_{ij}I_0(m+i,n+j)]=f[R_0(m,n)] \tag{1}$$

where I_0 (m,n) is the pixel gray level of the original image; $I(m,n)$ is the image gray level after the lateral inhibition competition; a_{ij} is the lateral inhibition coefficient of the pixel to the central pixel in the ij location in the network; f is a function of inhibiting the competition relationship between output and input; and R_0 (m, n) is a function of network inhibition and competition.

The specific flow chart of the algorithm is shown in Fig.2.

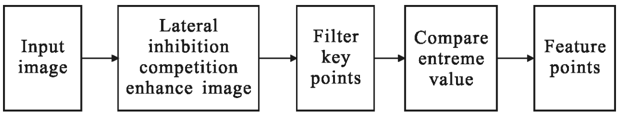


Fig.2 Flow of feature point detection based on lateral inhibition competition

2.1.1 Lateral inhibition competition enhancement image

We select the inhibition competition function of the 3×3 network, taking a pixel point $I_0(m, n)$ in the image as an example, the center point weight is a_{00}, and the other points weight is a. The lateral inhibition competition function is[13]:

$$R(m,n)=a_{00}\times I_0(m,n)+a\times[\sum_{i=-1}^{1}\sum_{j=-1}^{1}I_0(m+i,n+j)-I_0(m, n)] \tag{2}$$

Based on the principle of lateral inhibition competition: $a_{00}=1$, $a=-0.125$, lateral inhibition competition coefficient of 3×3 network[14], as shown in Fig.3.

−0.125	−0.125	−0.125
−0.125	1	−0.125
−0.125	−0.125	−0.125

Fig.3 3×3 meshwork lateral inhibition competition coefficient

The lateral inhibition competition function $R(m,n)$ of the pixel point $I_0(m,n)$ can be obtained by bringing the coefficients in the Fig.3 into the formula (2), the image is enhanced by this function, and the enhanced image is $I(m,n)$.

2.1.2 Screening key points

The Gauss function is used to smooth the image I (m,n) to reduce the influence of noise, then, the standard deviation of image $I(m,n)$ is calculated as threshold T. The point that is greater than the threshold T is chosen as the candidate bright feature point, and the point less than the threshold $-T$ is chosen as the candidate dark feature point to complete the key point selection.

2.1.3 The extreme value comparison

In the image of $I(m,n)$, the candidate bright pixel feature value of the pixel and the adjacent points in the 8 directions around the value, if local maxima, the bright feature points, the dark pixel candidate feature point values are compared with the pixel value the adjacent point around 8 directions, if local minima, the dark feature points.

At this point, the detection of the feature points in the image is completed, and two feature points are obtained, the bright feature points and the dark feature points.

2.2 Feature description

The SIFT feature descriptor is fine in the reference image and the under registration image respectively on the bright and dark feature point feature description, SIFT feature descriptor is constructed with the gradient statistics method, with better illumination invariance, uniqueness, robustness, can reduce the gray difference between the reference image and the under registration image.

2.3 Feature matching

Take the sets of bright feature points as an example, the nearest neighbor matching strategy to complete the initial feature matching, two of the initial matching points set of A and B; and then use the direction consistency constraint strategy eliminate obviously wrong matching points; the RANSAC algorithm[15] is used to complete the matching points on the purification of A and B set.

Taking the initial matching point pair A as an example, the specific implementation steps of the direction conformance constraint strategy are as follows:

(1) Calculation of the direction of motion for all matching point pairs.

$$\text{Theta}(i)=\arctan\frac{\Delta y}{\Delta x+\gamma} \tag{3}$$

where i=1,2, $\cdots$,num, num is the number of matching points in the set A for the matching point.

In the formula, $\Delta y=y_2(i)-y_1(i)$, $\Delta x=x_2(i)-x_1(i)$, $(y_1(i), x_1(i))$ and $(y_2(i), x_2(i))$, represent the row and column coordinates of the matching point pair on the matching point pair in the set A of the set i。 In order to avoid the case in which the denominator is 0, order $\gamma=\max(n_1,n_2)$, n_1, n_2 is respectively the number of columns for the reference image and the under registration image, the $\Delta x+\gamma$ must be more than 0.

(2) Moving the motion direction of all matching points to the interval [0°,180°], the expression is as follows:

$$\text{Theta}(i)=\frac{180\times\text{Theta}(i)}{\pi}+90 \tag{4}$$

(3) Motion direction histogram of matching point pair.

$$\text{Theta}(i)=\text{ceil}\left(\frac{\text{Theta}(i)}{5}\right) \tag{5}$$

Ceil said rounding up. The motion direction histogram matching points with 5° for a total of 36° interval, when Theta(i) falls into a certain interval, the corresponding statistical value of the interval is added to 1.

(4) In order to preserve the matching points of the right and left neighboring regions, we keep the direction of the histogram of the moving direction histogram and the corresponding matching points, so we finish the process of eliminating the error matching points by matching the spatial geometric relations of the matching points.

In the same way, the matching of the dark feature points of the reference image and the under registration image is matched. After that, two matching point pairs are merged, and a new match point pair set is obtained.

2.4 Reliability determination

For two matching points to set A and B, two projection transformation models $H_1=[a_1,a_2,x_1;a_3,a_4,y_1;a_5,a_6,1]$, $H_2=[b_1,b_2,x_2;b_3,b_4,y_2;b_5,b_6,1]$ are calculated by using the least square method. In order to ensure the reliability of image registration results, the two image transformation models must be the same or close to the image transformation model to be reliable. The similarity between the approximate displacement components x_i and y_i, i =1, 2 in the projection transformation model is measured by the next formula.

$$\begin{cases}|x_1-x_2|<\varepsilon\\|y_1-y_2|<\varepsilon\end{cases} \tag{6}$$

where ε is the threshold. When the approximate displacement components of the two projection models satisfy Eq.(6), the image transformation models are all reliable. When the matching points are set to A and B, the new projection transformation model H is calculated, and the registration between images is achieved through image interpolation algorithm.

3 Experimental results and analysis

In order to verify the effectiveness of the algorithm, we carried out simulation experiments in the environment of Matlab 2014a on the platform of memory 4 GB and processor 3.40 GHz, and carried out the analysis of the experimental results.

Considering the real-time performance of the algorithm and the image characteristic information requirement, in this paper the reference image (Fig.4) resolution is about 0.44 m, the size of the reference image and the under registration image (Fig.5) is 227×227, the size of the image and the scene holding range are appropriate.

Fig.4 Reference image

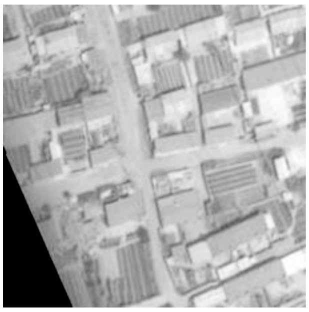
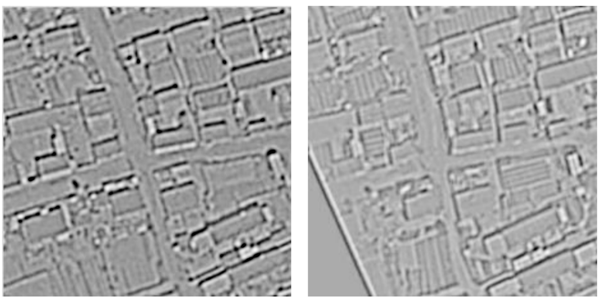


Fig.5 Under registration image

3.1 Comparison and analysis experiment of algorithm matching performance

Figure 6 shows the reference image and the under registration image after the lateral inhibition competition is enhanced. From the graph, we can see

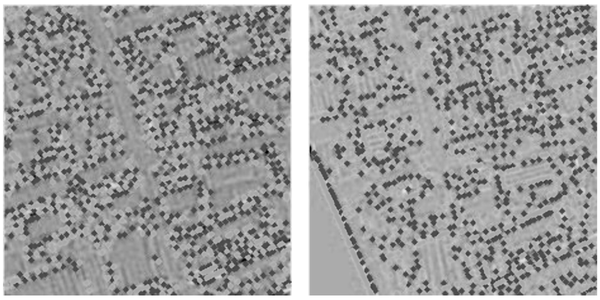


(a) Enhance result of reference image (b) Enhance result of under registration image

Fig.6 Image enhance result of lateral inhibition competition

that after the enhancement of lateral inhibition, the gray difference of the image has been reduced, and the details of the image edge have been enhanced.

Figure 7 shows a feature point detection algorithm based on lateral inhibition competition for feature points detection in the reference image and the under registration image, where the black dot represents the bright feature points, and the white points represent dark feature points.



(a) Feature point detection of reference image (b) Feature point detection of under registration image

Fig.7 Feature point detection result

SIFT algorithm, Harris+SIFT algorithm, FAST+SIFT algorithm and a total of 4 algorithms in this paper are compared.

Compared with the experimental data in Fig.8, it is found that the feature distribution is the most uniform and uniform distribution feature is used to improve the accuracy of subsequent image registration.

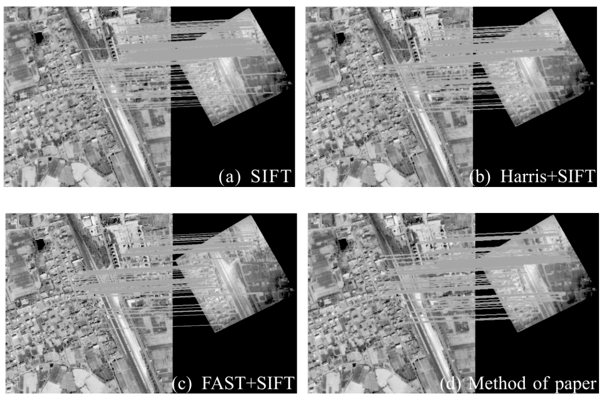


Fig.8 Registered result of the four algorithm

In order to match the performance of each algorithm for objective evaluation, this paper uses the correct matching points and matching algorithm, the correct rate of total time, a single correct matching points took 4 evaluation indexes to analyze quantitatively the efficiency of the algorithm, the correct matching rate[16] (CorrectRate) defined as follows:

$$\text{CorrectRate}=\frac{\text{matches}}{\min(N_1+N_2)} \tag{7}$$

where matches represents the number of correct matching points; N_1 represents the number of features detected in the reference image; and N_2 represents the number of features detected in the image to be registered.

Tab.1 Data table of the matching result

Algorithm	Correct matching points	Accuracy of matching	Total time/s	Time of alone correct matching point/s
SIFT	19	0.016	3.255	0.171
Harris+SIFT	32	0.022	1.320	0.041
FAST+SIFT	34	0.014	0.89	0.026
Method of paper	115	0.024	1.232	0.011

From Tab.1 we can see that this algorithm has better timeliness, 1.232 s than FAST algorithm is slow, but the rest of the index are optimal, especially the algorithm to obtain the correct matching points greatly exceeds the number of the other three algorithms, for further improve the accuracy of image registration has a great effect.

3.2 Experiment on accuracy analysis of algorithm registration

Figure 9 shows the results of the registration of aerial images under this registration algorithm.

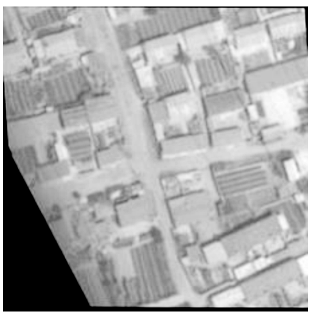


Fig.9 Registered image

In order to compare and analyze the registration accuracy of each algorithm, we use absolute difference measure (SAD), squared difference metric (SSD) and product correlation metric (PROD) to carry out quantitative analysis. Three indicators are defined[17] as:

$$\text{SAD}=\sum_{m=1}^{M}\sum_{n=1}^{N}|X(m,n)-Y(m,n)| \tag{8}$$

$$\text{SSD}=\sum_{m=1}^{M}\sum_{n=1}^{N}(X(m,n)-Y(m,n))^2 \tag{9}$$

$$\text{PROD}=\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}X(m,n)-Y(m,n) \tag{10}$$

where $X(m,n)$ is the reference image; $Y(m,n)$ is the image after the registration; M and N are the number of the ranks of the images. In order to eliminate the influence of light change on the accuracy of registration, the side suppression enhancement and normalization of $X(m,n)$ and $Y(m,n)$ were carried out in the experiment. Of the three evaluation indicators, the smaller the value of SAD or SSD, the higher the similarity between the two images; the greater the value of the PROD, the higher the similarity between the two images.

Tab.2 Registered precision comparison

Algorithm	SAD	SSD	PROD
SIFT	3 747	486	0.227 1
Harris+SIFT	4 126	551	0.220 3
FAST+SIFT	3 828	500	0.225 5
Method of paper	3 156	382	0.241 1

From the comparison of the indexes in Tab.2, it can be seen that the image registration accuracy of this algorithm is better than the other 3 algorithms. The experimental results show that the algorithm improves the matching speed and also ensures the registration accuracy.

4 Concluding remarks

Due to the geometric distortion of the original visible light aerial images, we must find a robust registration algorithm to achieve the accurate registration of aerial images. Feature based image registration is an effective registration method that can solve this problem at present. However, the common algorithm still has some problems such as low accuracy, poor stability and large amount of computation. The characteristics of the lack of information and uncertainty to the gray change feature detection problem based on aerial remote sensing images often appear, propose a registration algorithm based on the lateral inhibition compete. The algorithm solves the problem of registration speed and accuracy to reach the equilibrium point in image registration, achieve accurate registration of aerial image to visible light.

References:

[1] Ye Yuanxin, Shan Jie, Peng Jianwei, et al. Automated multispectral remote sensing image registration using local self-similarity [J]. ***Acta Geodaerica et Cartographica Sinica***, 2014, 43(3): 268-269. (in Chinese)

[2] Zhang Yiwen, Hou Yuanbin, Kang Qian, et al. Image registration algorithm based on EPF and maximum cross-correlation for target recognition of manipulator [J]. ***Application Research of Computers***, 2012, 29(12): 4762-4763. (in Chinese)

[3] Fan Youchen, Zhao Hongli, Sun Huayan, et al. Application of cross-correlation algorithm in moving target range-gated three-dimensional laser active imaging [J]. ***Infrared and Laser Engineering***, 2016, 45(6): 0617003. (in Chinese)

[4] Li Dan, Xiao Liqing, Tian Jun, et al. Multi-images mosaic algorithm based on improved phase correlation and feature point registration [J]. ***Computer Science***, 2018, 45(1): 314-316. (in Chinese)

[5] Moravec H P Towards. Automatic visual obstacle avoidance [C]//In Processing of International Joint Conference on Artificial Intelligence, 1977: 1146-1148.

[6] Harris C, Stephens M. A combined corner and edge detection [C]//Proceedings of the Fourth Alvey Vision Conference, 1988: 147-151.

[7] Smith S M, Brady J M. SUSAN-A new approach to low level image processing [J]. ***Int Journal of Computer Vision***, 1997, 23(1): 78-82.

[8] Wang Tianyu, Dong Wenbo, Wang Zhenyu. Position and orientation measurement system based on monocular vision and fixed target [J]. ***Infrared and Laser Engineering***, 2017, 46(4): 0427003. (in Chinese)

[9] Ouyang Huan, Fan Dazhao. Line matching for aerial image based on cumulative distribution constraint of the corresponding points [J]. ***Journal of Geomatics Science and Technology***, 2017, 34(4): 376-377. (in Chinese)

[10] Christopher Timmermann, Meg J Spriggs, Mendel Kaelen, et al. LSD modulates effective connectivity and neural adaptation mechanisms in an auditory oddball paradigm [J]. ***Neuropharmacology***, 2017, 39: 1023-1025.

[11] Du Hongwei. Research on biological lateral inhibitory mechanism and its application [D]. Nanjing: Nanjing University of Aeronautics and Astronautics, 2010. (in Chinese)

[12] Song Xuefei. Research and application of graph clustering algorithm based on lateral inhibition [D]. Changchun: Jilin University, 2017. (in Chinese)

[13] Wang Zhiqiang, Cheng Hong, Yang Guang, et al. Fast target location method of global image registration [J]. ***Infrared and Laser Engineering***, 2015, 44(S): 226-227. (in Chinese)

[14] Yun Haijiao, Wu Zhiyong, Wang Guanjun, et al. Image enhancement algorithm based on improved lateral inhibition network [J]. ***Infrared Physics and Technology***, 2016, 76: 308-314. (in Chinese)

[15] Wang Weibin, Bai Xiaoling, Xu Qian. Feature image matching of SURF and RANSAC [J]. ***Journal of Harbin University of Science and Technology***, 2018, 33(6): 622-627. (in Chinese)

[16] Zhao Aigang, Wang Hongli, Yang Xiaogang, et al. Compressed sense SIFT descriptor mixed with geometrical feature [J]. ***Infrared and Laser Engineering***, 2015, 44(3): 1086-1089. (in Chinese)

[17] Hu Fangshang, Guo Hui. Printing image registration based on ROI template [J]. ***Journal of Donghua University***, 2016, 42(4): 583-584. (in Chinese)