

## A Quick Image Registration Algorithm Based on Delaunay Triangulation

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### Abstract

*The traditional image matching algorithms adopt more complex strategies when dealing with mismatch caused by a lot of noise. In this paper, a simple, intuitive and effective noise processing algorithm is proposed based on Delaunay triangulation in computational geometry. The algorithm extracts feature points using SIFT method, respectively establishes Delaunay triangulation in multi-spectral and panchromatic images, and removes the feature points that three points are collinear and four points are on circle by Delaunay triangulation, obtains the registration images through the correspondence between the Delaunay triangulations. The effect of image registration is evaluated by objective method. In the image matching, Delaunay triangulation is introduced. The establishment of Delaunay triangulation is independent of the selection of initial values. In general, a unique Delaunay triangulation can be got when a feature point set is given, and it can provide the accuracy of the algorithm. The algorithm is simple and clear for converting a lot of mismatch noise to the operation of Delaunay triangulation. Experiment results show the algorithm can keep the good rotation feature and translation invariance in SIFT method, the number of extraction feature points has been significantly reduced in the algorithm compared with SIFT method, registration speed and accuracy are better than the registration algorithm based on conventional SIFT method.*

**Keywords:** Image registration, Delaunay triangulation, Multi-spectral image, Panchromatic image

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### 1. Introduction

Image registration is an important step in the applications of image fusion, target recognition, change detection, image registration is the necessary preliminary work to improve the accuracy and validity of the above problems [1-4]. Image registration means determining the transformation parameters between images according to the similarity measure so that the two or more images from different sensors, angles, different time with the same scene transform to the same coordinate system and obtain the best match in pixel layer [5,6].

Image registration involves a lot of technology such as complex feature extraction, optimization algorithms, image segmentation, pattern recognition and matching, but it lacks of systematic theoretical guidance in many ways. Therefore, it is the development direction to improve the automation, registration accuracy and speed of the registration algorithms [7-9]. In response to the above difficulties, this paper presents a registration algorithm suitable for multi-spectral and panchromatic images to improve registration accuracy and speed.

### 2. Feature Extraction of Multi-Spectral and Panchromatic Images Through Traditional SIFT Method

Remote sensing image registration is the best matching process for two or more images, overlapped areas are geometric distortion or inconsistency in spatial coordinates, it is necessary to find the geometric transformation parameters for image registration.

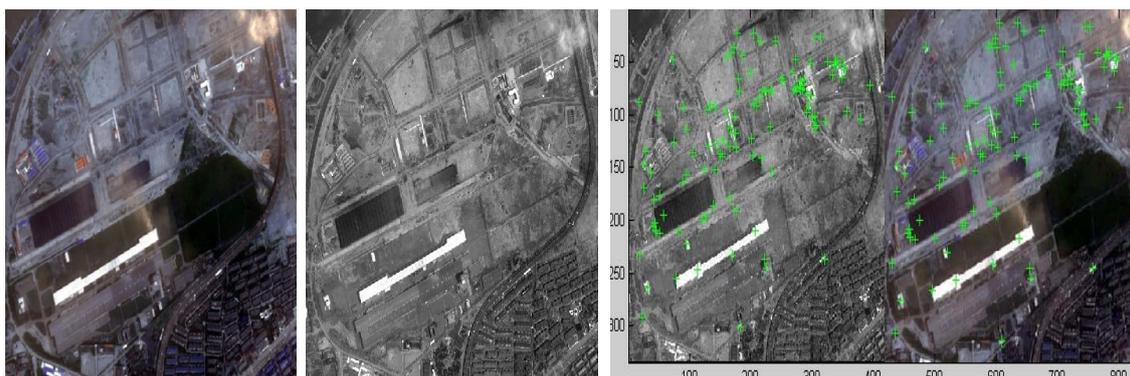
In the common characteristic information, the point is the most usual feature. The method detects feature points of an image, describes the feature points according to the neighborhood of the feature points, and finally calculates the correspondence relationship between the feature points in the original images. Point feature has lower calculation, and does

not damage the important gray information of an image, therefore, it can greatly improve the registration speed and accuracy. Harris detection method is a traditional feature point extraction method, which is very sensitive to changes in image scale, and it largely leads to limitation of the application scope. Harris feature points can get accurate registration results with only rotation, translation, and small-scale transform of an image, but for the large-scale transform of an image, the method can not guarantee the correct registration results. Later, the researchers have proposed a large number of feature point detection methods with scale invariance, affine invariance, as well as local invariance.

David Lowe summarized the existing invariant feature-based techniques, and formally proposed a local feature based on scale space, which can remain invariant when translation, rotation, scaling, or affine transformation, and he proposed a descriptor based on this feature in 2004. He named this Scale Invariant Feature Transform, that is SIFT algorithm later [10].

SIFT method detects a feature in the scale space and determines the scale and location of the feature points, uses the main direction of the neighborhood gradient as the direction feature of the feature point in order to enable the operator independent of the scale and direction. The features by SIFT method can be used for reliable matching with same object or scene, they are invariant to image scaling and rotation, and have good robustness in illumination changes, noise, and affine transformation. In addition, SIFT features are the local characteristics of an image, they can correctly match with high probability.

This paper respectively extracts feature points in multi-spectral and panchromatic images using the SIFT method, feature points include position, scale, size and direction. Figure 1 gives the feature points extracted by the SIFT method in multi-spectral and panchromatic images.



(a) A multi-spectral image (b) A panchromatic image (c) Feature points using the SIFT method

Figure 1. Extract Feature Points Using The SIFT Method

### 3. Selection feature points through Delaunay triangulation

Feature is a structure property shown by one or some pixels relative to its neighborhood, it generally better maintains invariance in translation and rotation. Point feature is a basic feature, but its scope is the most extensive, and its calculation and description is very simple, so feature points are selected as the registration points in the paper.

#### 3.1. The property of Delaunay triangulation network

In the field of geosciences, a large number of discrete data often need to be processed, the data distribute uneven, therefore, it needs to consider how to rationally and effectively use the valuable data. In 1908, G.Voronoi firstly limited the effective scope of each discrete point in mathematics, that is the scope of effectively reflecting regional information, and defined the Voronoi diagram on two-dimensional plane (referred to as *V-graph*). In 1911, A.H.Thiessen applied *V-graph* in the average rainfall of big regions. In 1934, B.Delaunay evolved Delaunay triangulation from *V-graph* (referred to as *D-triangulation*). Since then, *V-graph* and *D-triangulation* have become universally accepted and widely used to analyse discrete data.

Delaunay triangulation is the associated graph of  $V$ -graph [11] (also known as Thiessen diagram, Dirichlet map, Vigner-Seitz graph).  $V$ -graph is defined as follows. Supposing  $V=\{v_1, v_2, \dots, v_N\}$ ,  $N \geq 3$ ,  $V$  is a set of points in Euclidean plane. And these points are not collinear, any four points are not cocircular.  $d(v_i, v_j)$  is the Euclidean distance of  $v_i, v_j$ . Suppose point  $x$  is on the plane,  $V(i)=\{x \in E^2 \mid d(x, v_i) \leq d(x, v_j), j=1, 2, \dots, N, j \neq i\}$  is called Voronoi Polygon ( $V$ -Polygon), all  $V$ -polygons of each point jointly constitute  $V$ -graph.

$V$ -graph on the plane can be seen as each point in point set  $V$  as a growth core, expand outward in the same rate, until they meet each other and form the graphs on the plane. In addition to the outermost point of the formation for open areas, the rest points form convex polygons [12].

$D$ -triangulation is  $V$ -polygons with common edges, and is called adjacent  $V$ -polygons. Connecting all adjacent  $V$ -polygon growth center formed the triangle network is called the  $D$ -triangulation network.

The outer boundary of  $D$ -triangulation is a convex polygon, which consists of convex set connected  $V$ , often referred to as convex hull.  $D$ -triangle has two very important properties.

Empty circle property. Delaunay triangulation is unique (any four points cannot be cocircular), in  $D$ -triangle formed by point set  $V$ , its circumcircle of each triangle contains no other points in  $V$ , it is shown in Figure 2.

The largest minimum angle property. In the triangular network formed by point set  $V$ , the minimum angle in the triangle of  $D$ -triangulation is the largest. In this sense, Delaunay triangulation is "the closest to the regularization" triangular net. Specifically refer to the convex quadrilateral diagonal formed by two adjacent triangles, when exchanging, the minimum angle of the six interior angles no longer increases. It is shown in Figure 3.

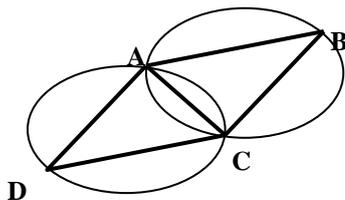


Figure 2. Empty Circle

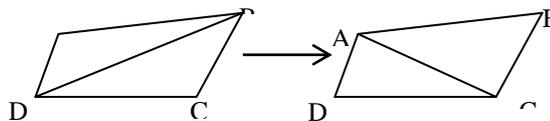


Figure 3. The Largest Minimum Angle

These two properties determine  $D$ -triangulation has great application value. Meanwhile, it is also the unique and best two-dimensional plane triangulation. Miles proved that  $D$ -triangulation was "good" triangulation. Sibson found "in a finite point set, there is only a partial and isometric triangular network, which is  $D$ -triangulation". Lingas further demonstrated that "in general,  $D$ -triangulation is optimal". Tsai thought that "in Euclidean plane, there is no more than three adjacent points in a circle,  $D$ -triangulation is unique".

These two properties effectively ensure Delaunay triangulation is the optimal triangulation closest to equiangular or equilateral, and make the control points distribute as evenly as possible in each small triangle.

Delaunay triangulation helps to avoid narrow or too small acute triangle in the case of points evenly distributed. Triangles in triangulation should all be acute triangles, or three edges roughly equal to each other, the triangles do not cross and overlap. Delaunay triangulation is closest to equilateral triangulation. In various two-dimensional triangulation, only Delaunay triangulation can both meet the global and local optimization.

### 3.2. Selection of Feature Points

Select appropriate feature is particularly important in registration. In normal circumstances, the best choice is in the absence of deformation trend, and registration requires enough points, evenly distributed as possible in the whole image, in order to ensure the accuracy of registration. In this paper, we experimented a variety of feature point extraction methods, then we respectively used the SIFT to extract feature points for multi-spectral and panchromatic images, which can give the coordinates of feature points, scale size and

orientation for multi-spectral and panchromatic images. In this algorithm, remove duplication matches and multiply to one matching points, then establish Delaunay triangulation, remove three collinear or four cocircular feature points by Delaunay triangulation. Determine the homologous control point pairs by the Euclidean distance, in order to reduce the false match rate. By using the homologous control point pairs, make affine transformation between multi-spectral and panchromatic images through the least square method, get transformation parameters, calculate the location between registration images. The valid basis of multi-spectral and panchromatic image registration using triangulation is listed as follows.

(1) The nearest. The nearest three neighbor points form a triangle, and each segment (triangle side) does not intersect to each other.

(2) Uniqueness. Eventually get consistent results no matter where to start.

(3) Optimality. If a convex quadrilateral diagonal formed by any two adjacent triangles is interchangeable, the smallest inner angles for two triangles do not become bigger.

(4) The most rule. If the minimum angle of each triangle in the triangulation is in ascending order, the minimum angle of the Delaunay triangulation is the maximum value.

(5) Regional. Increment, deletion, movement one vertex only affects the neighboring triangles.

(6) Convex polygon shell. The outermost boundary of the triangular network forms the shell of a convex polygon.

Since the feature points used in this paper is adopted as control points, the feature points are generally concentrated in the feature lines, which is consistent feature of Triangulated Irregular Network (TIN). The biggest advantage of TIN is the accurate description of the complex terrain. We can establish a triangular network for the whole control points in the image, establish dense triangulation in larger undulating regions, and construct sparse triangulation in the flat regions.

Common construction triangulation methods include angle judgment method, Thiessen Polygon and Delaunay triangulation. No matter where to build Delaunay triangulation net, Delaunay triangulation is unique as long as the feature points do not change.

In this paper, select Delaunay triangulation in the experiments. In the process of establishment network, each control point participated in the network structure, there is no cross, cracks and other irregularities. Construct procedure of Delaunay triangulation is as follows.

(1) Traverse all scattered points, find the inclusive case of the point set, get the initial triangles as the point set convex hull, and place it into the linked list of the triangle.

(2) Insert the scattered points for the point set in order, find out the triangle whose circumcircle contains the insertion points in linked list of the triangle, delete the public sides affect the triangle, connect the insertion points with all vertices influencing the triangle, thus complete a point insertion in the linked list for Delaunay.

(3) According to optimization criterion, optimize the locally and newly formed triangles, put the formed triangle into the linked list for Delaunay triangle.

(4) Perform step (2) and (3), until all scattered point insertion is over.

In this paper, respectively construct Delaunay triangulation for multi-spectral and panchromatic images using the delaunay function in Matlab. Delaunay triangulation for multispectral and panchromatic images are constructed as shown in Figure 4.

In Figure 4 (c) is to respectively extract feature points in multi-spectral and panchromatic images using traditional SIFT algorithm, feature points include duplication matches, multiply to one matching points, three collinear or four cocircular feature points, the total number is 112. The number of matching points after removal duplication matches, multiply to one matching points is 97. The number of matching points after removal three collinear or four cocircular feature points by Delaunay triangulation is 91. The intersection of straight lines in Figure 4 (d) shows the mismatch by using traditional SIFT algorithm.

It can be seen in Figure 4, Delaunay triangulation can automatically adjust the grid size according to the ground fluctuation and complexity in the overlapping areas. Select fewer points in flat regions, form larger triangles. In ground fluctuation and complexity, form smaller triangles through further matching interpolation, all triangles are acute triangles.

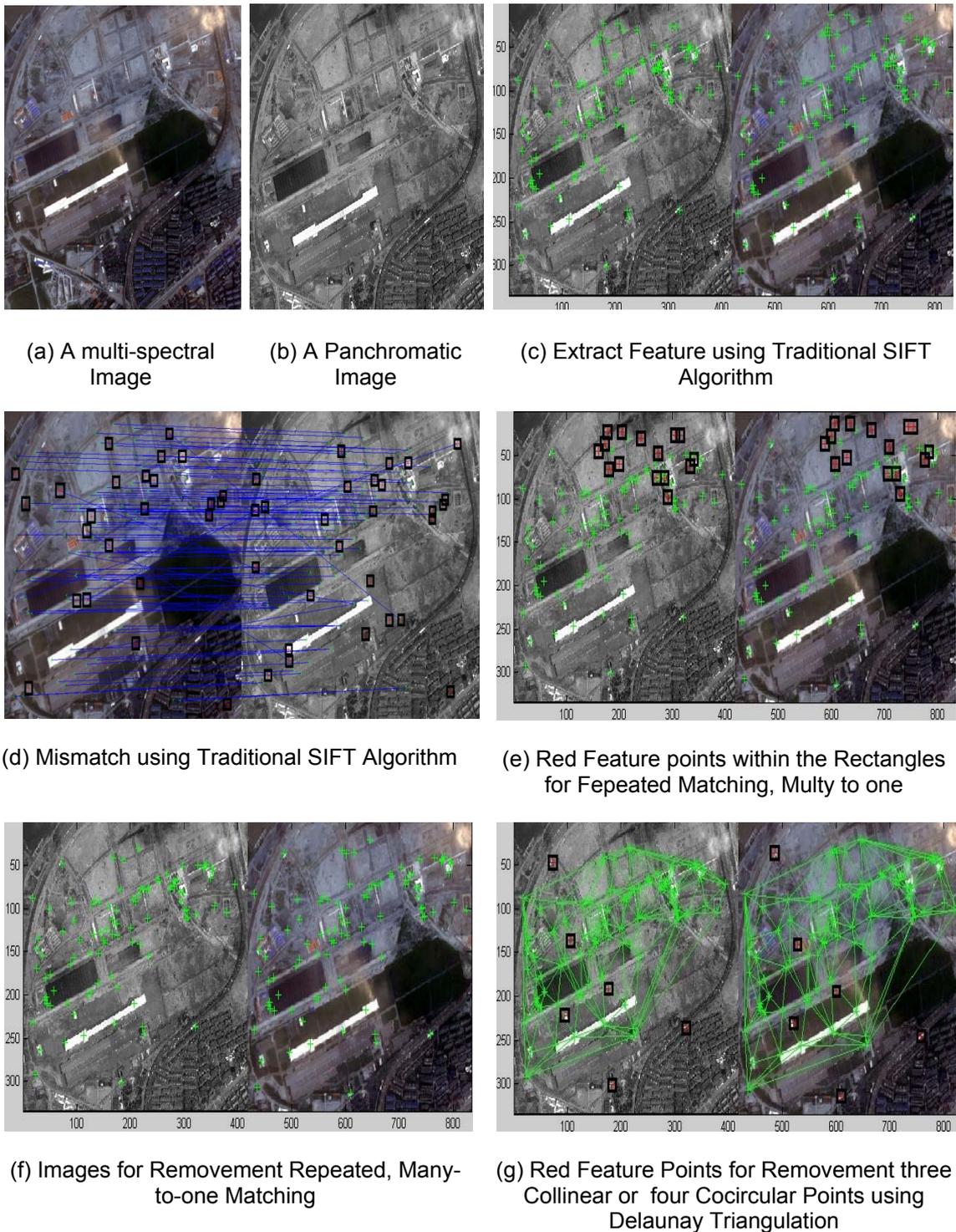


Figure 4. Construct Delaunay Triangulation Through Feature Points Extracted by SIFT Method

#### 4. A New Registration Algorithm Based on Delaunay Triangulation

Matching method based on SIFT descriptor has successfully applied in many fields, such as target identification, panoramic image mosaicing. However, the SIFT algorithm is still less applied in remote sensing image registration. The main reasons are that the traditional SIFT algorithm adopts Lowe's the nearest neighbor and next nearest neighbor distance ratio method, threshold is always chosen empirically, accuracy of remote sensing images for

complex matching feature points is lower. The accuracy of matching points will directly affect the subsequent image registration accuracy.

In image registration on the basis of feature points, feature point extraction needs to be considered firstly. When extracting feature points, feature points need to be significant and evenly distributed, and the number is not too fewer. Feature extraction is more complex, and it needs to find a stable, effective and simple feature extraction operator.

SIFT features have many fine features, but there are still some shortcomings listed as following:

(1) Because feature detection needs to search for multi-scale space, which requires a lot of convolution operation, and in order to produce feature point descriptors, require multiple weighted histogram operations. All these operations include a large number of floating point operations, therefore, relative to the number of its feature points, the computational complexity of algorithm is higher, and the computation is larger, speed is lower.

(2) SIFT features are firstly applied to target recognition, which needs to detect feature points as many as possible. However, large number of features will increase feature matching time.

(3) SIFT feature set is not very significant, there are still some instability points in the set. Many feature points detected by SIFT algorithm cannot describe contour features, they are neither edge points nor corner points.

For remote sensing image registration with different seasons, resolutions, and sensors, the feature point matching is more complex than general images. Traditional SIFT algorithm cannot get rid of some error match point pairs for remote sensing images. Meanwhile, the traditional SIFT method does not take into account repeated matching, multiply to one matching points and so on, and it is with larger space to optimize matching accuracy.

When calculating the directions of SIFT key points, the same key point may have a primary direction, one or more auxiliary direction. In the proposed algorithm, we shall classify them into different feature points. These feature points may possibly all or in part generate the correct match points, but they are actually the same points, it will generate repeated mismatch. SIFT feature match with exhaustive search may also produce one to many, many to one matching. These false matches needs to be eliminated one by one, otherwise it will affect the subsequent image registration accuracy. Lei Xiaoqun and etc. analysed the main error sources in SIFT feature point matching, possible error pairs were eliminated gradually, and precise pairs were extracted as many as possible. Then use these matched points as registration control points, affine transformation and tiny facet primitive rectifying were tested on different time and resolution images. Experimental results showed this algorithm could get higher accuracy in registration.

While the feature points are described by the SIFT algorithm, the descriptor is a 128-dimensional vector, which caused excessive computation in the course of descriptor and subsequent registration. Many scholars have proposed various improved SIFT methods, principal component analysis (PCA) can reduce the descriptor dimensionality, thus, it reduces the computational complexity. Re and Sukthankar etc. used PCA method to reduce descriptor dimension in the normalized gradient field, the stability was higher, but the precision was lower. Speeded Up Robust Features (SURF) method reduced the computational complexity, which was suitable for larger changes in image resolution, but under the affine transformation and illumination changes, the effect was unsatisfactory. Mikeolajczyk proposed expansion SIFT descriptor Gradient Location-Orientation Histogram (GLOH), it strengthened distinctive quality for the characteristic descriptor, but the effect on the fast image matching was not satisfactory. Wang Tianjia reduced dimensionality of high-dimensional descriptor for SIFT algorithm, simultaneously strengthened the neighborhood pixel information of the key points, and achieved a fast match effect.

In the traditional algorithm for the feature points extracted from two images, firstly calculate the nearest neighbor matching of each feature point for the first image to the second image, which is the key point descriptor vector of minimum Euclidean distance. The traditional SIFT algorithm used Lowe's nearest neighbor and sub-nearest neighbor distance ratio to match. When the ratio is less than a threshold corresponding to the point, it is as the correct match, otherwise it would be abandoned, ratio usually uses Lowe's recommended value of 0.8. For remote sensing image registration with different resolutions or sensors, the matching feature points are more complex than the general images. Although the traditional SIFT algorithm uses a smaller ratio value to obtain better match results with higher accuracy, testing results for a

large number of remote sensing images show that even with a smaller ratio value, it still cannot get rid of some errors in remote sensing images.

This paper presents an improved registration algorithm based on Delaunay triangulation to achieve multi-spectral and panchromatic image registration, which is on the ground of constrained Delaunay triangulation feature point registration. The specific steps are as follows.

- (1) Respectively extract feature points in multi-spectral and panchromatic images.
- (2) Even with a small ratio value, it still cannot completely get rid of the error points, and the number of feature points extracted is very little at this time, which is unfavorable in the following image registration. In order to extract many matching points, this paper uses the proposed ratio of 0.8 by Lowe, adopting the nearest neighbor and sub-nearest neighbor method for the initial match.
- (3) Based on the initial match points, the errors are eliminated one by one. Aiming at the traditional SIFT method does not take into account repeated matching, mutly to one matching points and so on, the paper compares the pixel coordinates for match points and traverses the corresponding points to remove duplication matches and mutly to one matching points in traditional SIFT method, and ensures the matching points unique and one-to-one.
- (4) In this paper, respectively construct Delaunay triangulation of the multi-spectral and panchromatic images. Remote sensing images can be divided into some grid areas by Delaunay triangulation in order to guarantee that feature points are examined in each grid. The improved registration algorithm based on SIFT can make the extraction feature points uniformly distributed, range feature points in each small triangle, and it can effectively improve the registration precision.
- (5) Revise the feature points by the Delaunay triangulation, remove three collinear or four cocircular feature points obtained by SIFT descriptor using the Delaunay triangulation.
- (6) To reduce the false match rate, Euclidean distance is introduced to determine the homologous control point pairs in this paper. Calculate the Euclidean distance between two feature points descriptor, that is to find out the nearest and sub-nearest neighbor feature point descriptors  $q_i'$  and  $q_i''$  with the feature points descriptor  $p_i$  by Euclidean distance. Then calculate the ratio of Euclidean distance of descriptors  $p_i$  and  $q_i'$ ,  $p_i$  and  $q_i''$ . If the ratio  $r$  is less than the specified threshold (Usually  $0.8$ , here  $0.8$ ), then consider successful match, point pairs  $(p_i, q_i')$  are a pair of matching points of image sequence, otherwise, the match fails.
- (7) Using the homologous control point pairs, obtain the affine transformation between multi-spectral and panchromatic images by adopting the least square method, obtain transformation parameters, calculate the location of the registration images, and get the registration results.

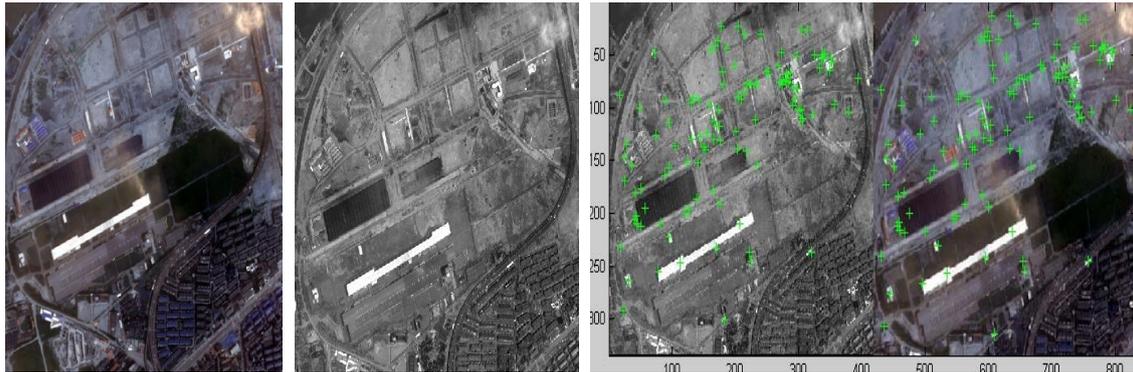
SIFT algorithm can detect a lot of feature points, the number of matching is more, this is one feature of SIFT algorithm. At first, SIFT features was used in target recognition, target recognition needs to match smaller targets from a large number of image database, therefore the smaller targets also need richer feature information. This is also very important to image registration with smaller proportion of overlap, because in this case we need to ensure that tiny image overlap still has enough feature points. Of course, image registration is different from object recognition, the registration for two images does not need too many match points, and this is the improvement in the paper.

Table 1. The Test Results

Performance	Traditional SIFT algorithm	The algorithm based on Delaunay triangulation
The number of feature points	296	251
Correct rate	64%	72%
Registration time(s)	1.5058	1.3852
RMSE	0.9665	0.6254

In this paper, a lot of multi-spectral and panchromatic images have been respectively tested by the traditional SIFT algorithm and the proposed algorithm in the paper, the test results are shown in Table 1. Experiment results show the proposed algorithm has significantly reduced the number of extraction feature points, improved the matching speed and reduced the mismatch rate, and improved the registration accuracy.

As an example, a registration result for the proposed algorithm is shown in Figure 5. The running time is relatively slower than only using SIFT control points in image registration without Delaunay triangulation. For multi-spectral and panchromatic images illustrated in Figure 4, the registration running time after Delaunay correction is 0.2098s, the registration *RMSE* is 0.6524, while the registration time by directly using SIFT control points is 0.215s, the registration *RMSE* is 0.6808



(a) A multi-spectral Image

(b) A panchromatic Image

(c) Extract Feature Points using Traditional SIFT Algorithm



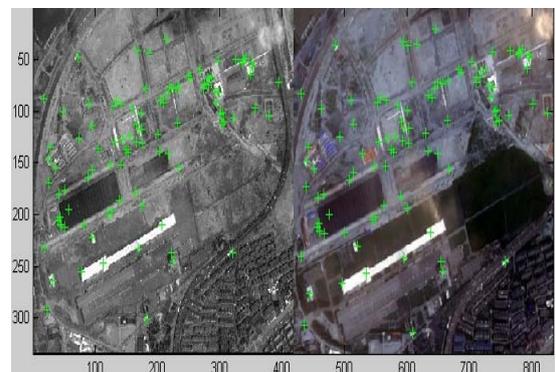
(d) Mismatch using Traditional SIFT Algorithm



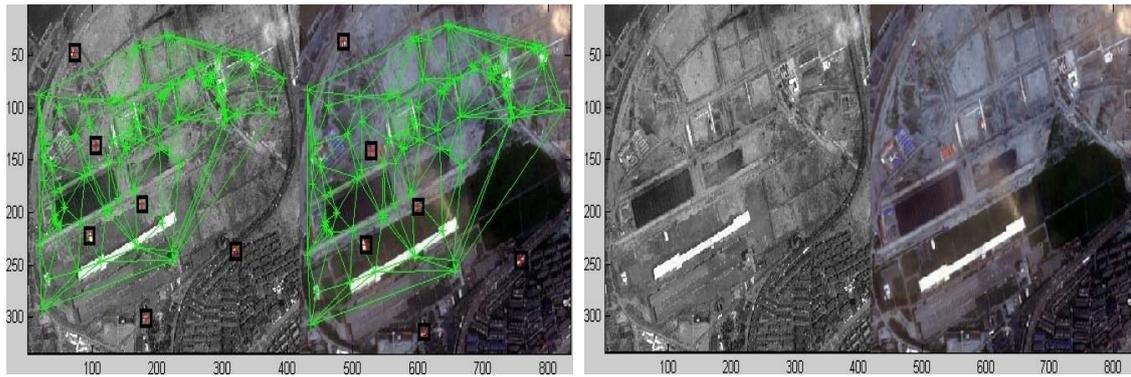
(e) Registration Images using SIFT Algorithm



(f) Red points for repeated, many-to-one matching extracted by traditional SIFT algorithm



(g) Images for removal repeated many-to-one matching



(h) Red feature points for removal three collinear or four cocircular feature points using Delaunay triangulation

(i) Registration images

Figure 5. Registration Results

**5. Registration Effect and Evaluation**

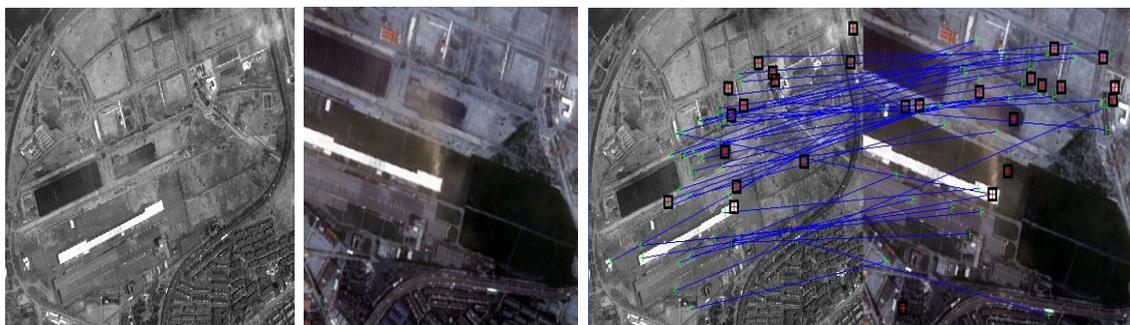
There are two registration accuracy analysis methods, one is statistical analysis of control points, Root Mean Square Error (RMSE). It is assumed that the matching control points can represent the similar characteristics, and determine the transformation relation between images. The other is direct comparison between the gray of images. Histogram matching of registration images is required. This paper uses *RMSE* as the quantitative evaluation of image registration results.

The *RMSE* between reference image  $S(x,y)$  and registration image  $T_1(x,y)$  is denoted as  $E_1$ , *RMSE* is defined as follows.

$$E_1 = \sqrt{\frac{\sum_{x=1}^M \sum_{y=1}^N [S(x, y) - T_1(x, y)]^2}{M \times N}}$$

where  $E_1$  reflects the difference between  $S(x,y)$  and  $T_1(x,y)$ , the smaller  $E_1$  is, the smaller difference is. The algorithm still has better registration effects when the image exists rotation and translation.

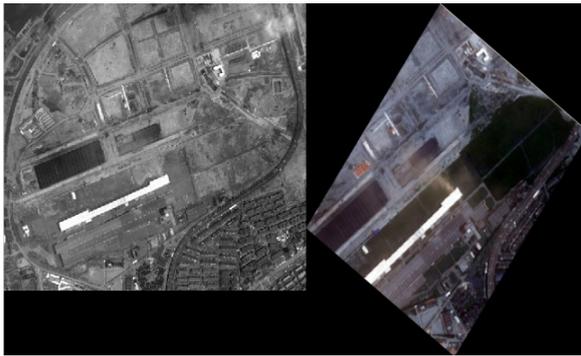
The experiment images with  $0^\circ \sim 360^\circ$  rotation can accurately register. Figure 6 shows the registration results in the case of rotation  $36^\circ$  for the multi-spectral image. The registration time is 0.1498s, and *RMSE* is respectively 0.6524 and 0.7452 before and after rotation. After rotation, the registration time is 0.1696s, *RMSE* is separately 0.6808 and 0.8733 in Figure 6 by the traditional SIFT algorithm, the result shows the proposed registration algorithm has stronger adaptability to rotation.



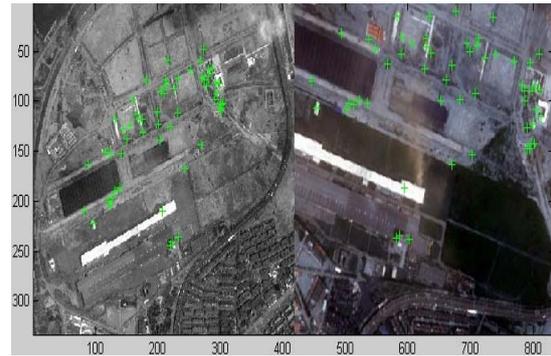
(a) A panchromatic image

(b) Rotation  $36^\circ$  for a multi-spectral image

(c) Mismatch by using ditional SIFT algorithm



(d) Registration images by using traditional SIFT algorithm



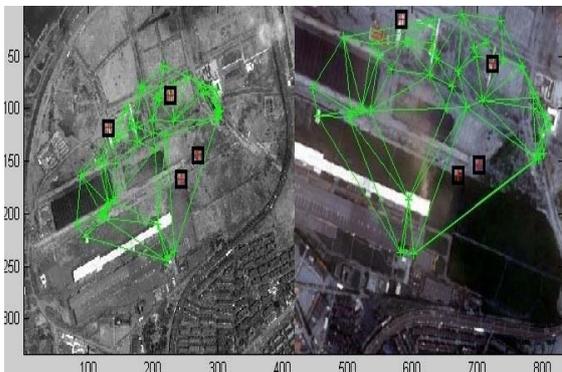
(e) Extract feature points using traditional SIFT algorithm



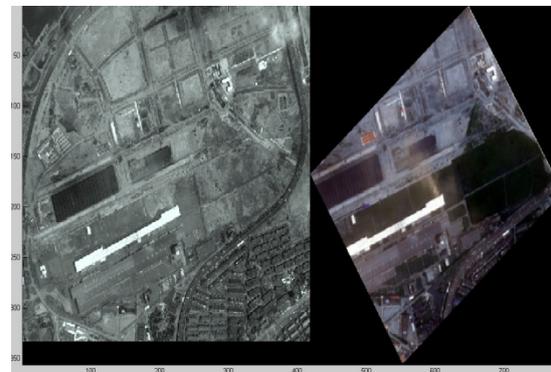
(f) Red feature points for repeated matching, multy to one



(g) Images for removal repeated many to one matching



(h) Red feature points for removal three collinear or four cocircular feature points using Delaunay triangulation



(i) Registration images

Figure 6. Registration Results

In Figure 6 (e), the total number of points is 69 respectively extracted in multi-spectral and panchromatic images using traditional SIFT algorithm, the feature points include duplication matches, multy to one matching points, three collinear or four cocircular feature points, the total matching number of points is 60. The red points within the rectangles show repeated matching, multy to one feature point matching in Figure 6 (f). The red points within the rectangles in Figure 6 (h) are removal three collinear or four cocircular feature points using Delaunay triangulation, the total number of matching points is 60 after removal repeated matching,

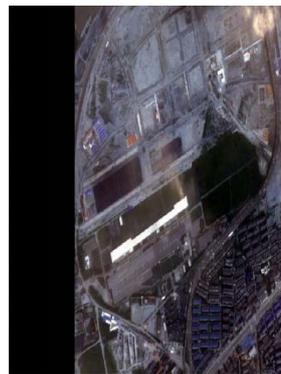
many-to-one matching. The total number of matching points is 56 after removal three collinear or four cocircular feature points. Figure 6 shows the registration algorithm still has a better effect in the case of rotation for the images.

The registration algorithm still has good results in the case of translation. The experiment images with left or right 0~500 pixels can accurately register. The registration results are shown in Figure 7 after right translation 230 pixels for the multi-spectral image. The registration costs 0.5863s, *RMSE* is respectively 0.6524 and 0.7558 before and after translation. In Figure 7, the registration costs 0.6935s, *RMSE* is respectively 0.6808 and 0.8952 before and after translation by using the traditional SIFT algorithm in the case of right translation 230 pixels for the multi-spectral image, it shows the registration algorithm has stronger adaptability to translation.

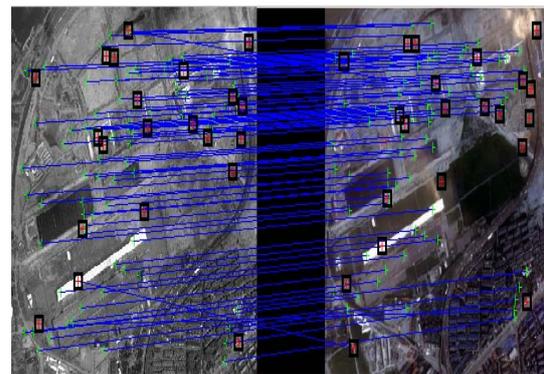
Mismatch images adopting traditional SIFT algorithm are illustrated by intersection of straight lines in Figure 7 (c). In Figure 7 (e), respectively extract feature points in multi-spectral and panchromatic images using traditional SIFT algorithm, the feature points include duplication matches, muly to one matching points, three collinear or four cocircular feature points, the total number of matching points is 119. In Figure 7 (f), the total number of matching points is 102 after removal duplication matches, muly to one matching points. In Figure 7 (h), the total number of matching points is 97 after removal three collinear or four cocircular feature points using Delaunay triangulation. The 97 feature points are practically used in the registration.



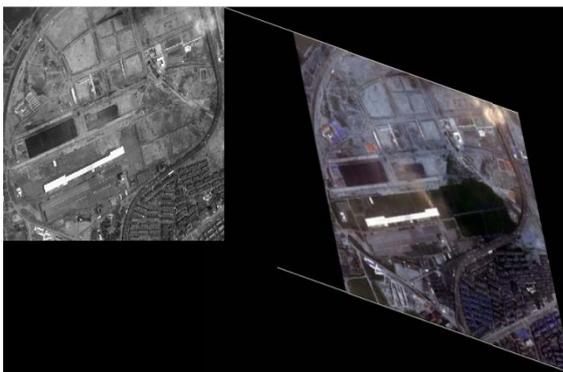
(a) A panchromatic image



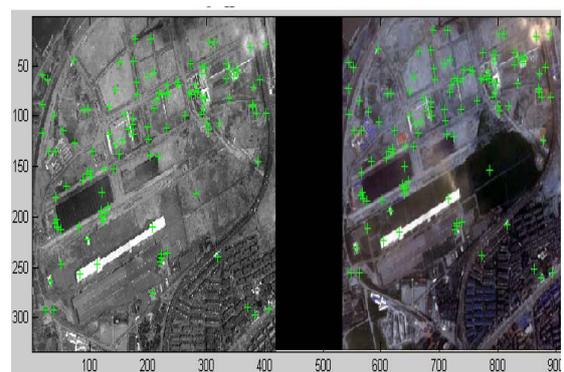
(b) Right translation 230 pixels for a multi-spectral image



(c) Mismatch by using traditional SIFT algorithm



(d) Registration images by using traditional SIFT algorithm



(e) Extract feature points using traditional SIFT algorithm

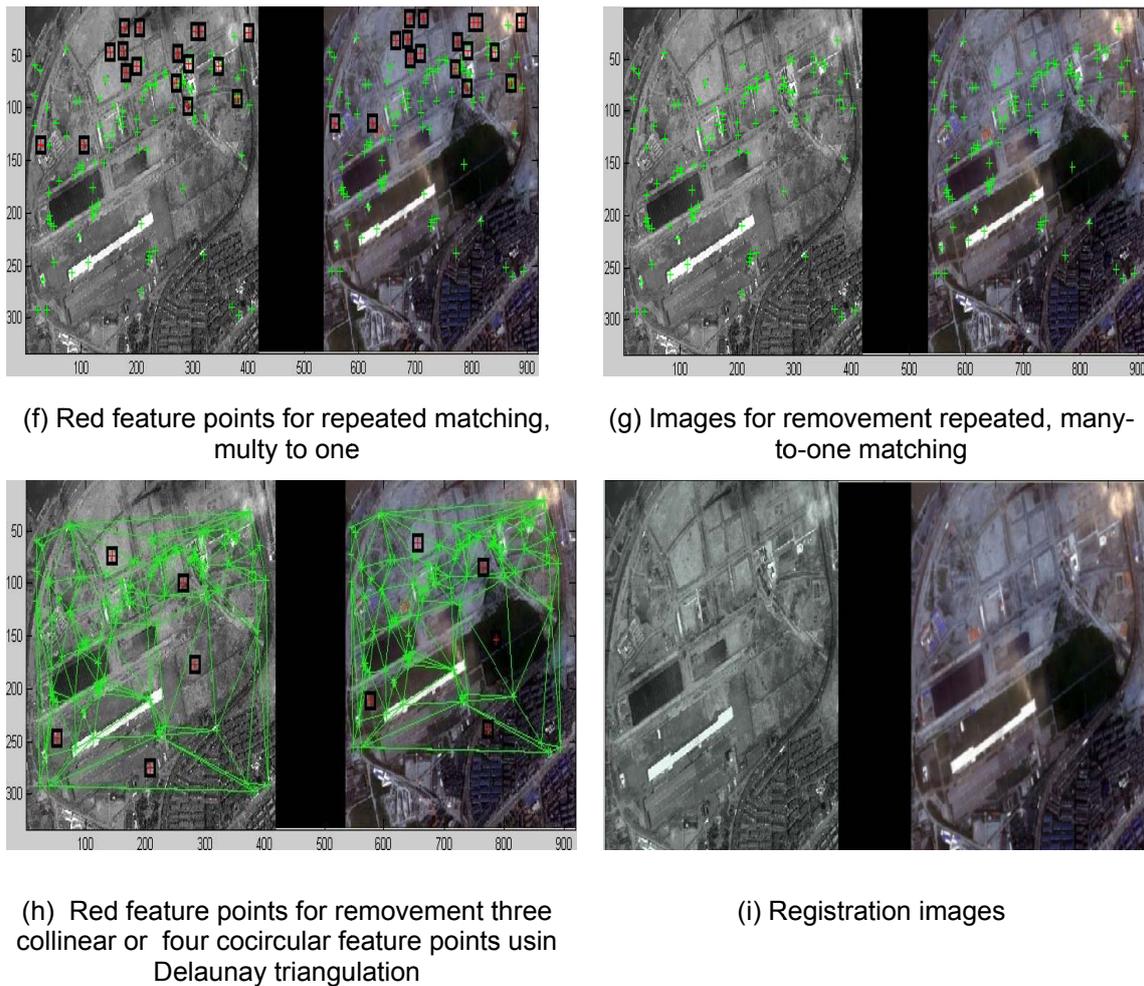


Figure 7. Registration Results

It can be seen from the results, the improved registration algorithm based on Delaunay triangulation can accurately register, improve the registration speed and precision in the case of certain translation and rotation.

## 6. Conclusion

The traditional image matching algorithms based on feature points need to adopt more complex treatment strategy in dealing with much noise caused by mismatches [13,14]. A simple, intuitive and efficient noise processing algorithm is presented using Delaunay triangulation in computational geometry. The algorithm is on the basis of the features extracted by SIFT method, respectively establishes Delaunay triangulation in multi-spectral and panchromatic images, and removes the feature points that three points are collinear and four points are on circle by Delaunay triangulation, obtains the registration images through the correspondence between the Delaunay triangulations. Delaunay triangulation is introduced in image matching. The benefit is a unique Delaunay triangulation can be got when a feature point set is given, and it can provide the accuracy of the algorithm. The algorithm is simple and clear for converting a lot of mismatch noise to the operation of Delaunay triangulation. Experimental results show the number of extraction feature points has been significantly reduced in the algorithm, which is helpful to improve the speed. The proposed algorithm does not affect the good rotation and translation

invariance for traditional SIFT method, registration speed and accuracy are better than the registration algorithm on the basis of conventional SIFT method.

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