A Fast Geometric Rectification of Remote Sensing Imagery Based on Feature Ground Control Point Database

Jian Yang and Zhongming Zhao

***Abstract*—**This paper, on the basis of the traditional design of database for ground control point, tries to founded a fast auto-correction method of satellite remote sensing imagery based on feature ground control point database which brings local feature points as the effective supplement and aims to achieve the automatic matching between feature ground control points and original images that need geometric correction and improve the rectified process utilizing random sample consensus (RANSAC algorithm). In this method, the author realize the auto-extraction of feature ground control points for ensuring speed and precise geometric correction of a high volume of satellite remote sensing images by means of analyzing feature ground control point database algorithm.

***Keywords*—**Ground Control Point (GCP) Database; feature matching; local invariance; feature ground control points

I. Introduction

Satellite remote sensing images require a certain number of ground control points. The traditional method of extracting ground control points is to identify the location of surface features and the landscape with obvious and distinctive features one by one in the original image utilizing some general or special image processing softwares on the basis of the prescribed projection reference system.

This method is time-consuming and laborious because of involving a process of artificial selection. And more badly is that by this process, the accuracy of measuring ground control points is great influenced by subjective factors and efficiency for geography correction is limited[1,2].

In addition, the utilization rate of repetition is also low. To enhance efficiency and quality of controlling information on data extraction of correction ground control points, management and shares of results of ground control points and so on, it is necessary to further make research on the areas such as design of GCP database and efficiency and accuracy of GCP auto-selection and so on.

Up to now, the study on the design of database for GCP has gained some achievements. Zhang Jixian and his colleagues have provided principles and methods for large images database of GCP. Based on this, China Surveying and Mapping Institute of Science and Technology collected 70% of the control points in the whole country and established a multi-level, multi-braided database with graph and image so that the level of GCP auto-selection has been improved to some degree. Moreover, Ying Jianhua and his colleagues utilized Pass Processing correction model to simplify the production process of precise geometric correction, reduce the workload on the GCP selection district and optimize the integrated management of correction GCP data of the remote sensing image. Adopting GCP database of graph and image for geometric correction has demonstrated some advantages such as high speed of selecting points, the wide application field and high utilization of repetition and so on[3]. Meanwhile, establishing GCP database of graph and image based on high-resolution remote sensing images can effectively raise accuracy of the national and provincial land resources investigation and assessment[4].

In view of the current precise geometric correction and orthophoto correction of high-resolution remote sensing images, the author has adopted the automatic registration algorithm based on local GCP to achieve the automatic detection and matching of GCP during the process of dealing with data. Therefore, the author put forward the establishment of feature ground control point database, that is, the database in which some information about GCP features is involved in the property management of GCP and applied in the process of matching. This paper tries to ensure the quick and precise geometric correction of a high volume of satellite remote sensing images by means of studying the GCP auto-detection and extraction algorithm.

II. Design of Feature GCP Database

2.1 Function of GCP database

Ground Control Point is the orthophoto meeting the requirements of geometric accuracy and also a small point with distinctive features which is selected from the topographic maps and whose possibility of changes in surface features is relatively small[5]. The control point of graph and image, the

Manuscript received October 31, 2008: Revised version received January 26, 2009. This work was supported by a grant from the National High Technology Research and Development Program of China (863 Program) No. 2007AA1202031

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expansion of the traditional one, is regarded as the center in the orthophoto map or topographic map and a certain range of images, the coordinate of the point and information about the position description including information of point coordinates (such as spheroid, projection, etc.) and images information (such as resolution, image type, coordination and access time, etc.) are stored. When the above images and property information are stored in the form of raster in a database, the database for GCP of graph and image has been formed[6].

2.2 Choice of data sources

Generally, data sources of GCP include digital raster topographic maps and aviation and aerospace orthophotos and so on. In this paper, the algorithm is based on high-resolution images, therefore, it is necessary to extract feature control points from remote sensing images such as Quickbird images, Spot5 images and domestic resources series of satellite images and so on. Whenever GCP database is used for design of some sensor, it can be fixed to be a single data source for facilitating the collection and management; Whenever GCP database is established on the multi-source sensor data, the quality of data source should be controlled on the following aspects: geometric accuracy of data, the color of images or topographic maps, contrast, clarity and so on[7].

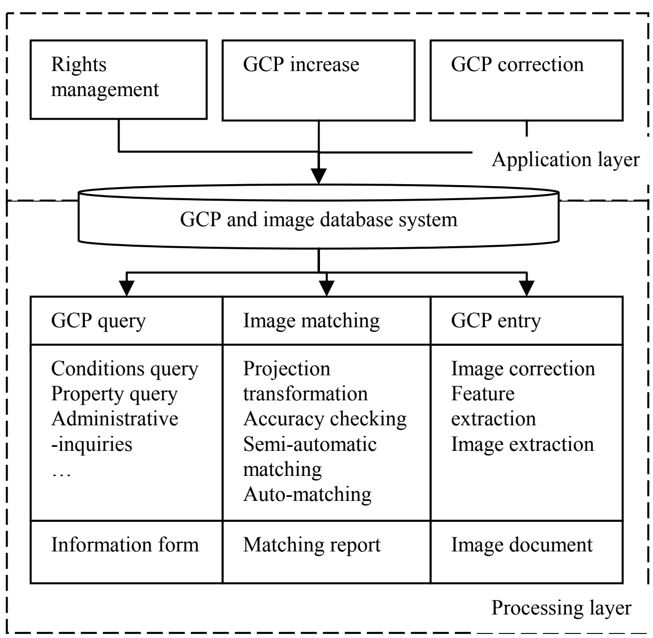

Fig.1 the function and structure diagram of GCP database

2.3 Data form of feature GCP

The establishment of feature GCP database needs to construct a GCP Table with relevant features and extract these control points to store some information about them in the database[1]. In this paper, the author proposed to extract some local invariant feature points as GCP and should record not only information about those points, but also the characteristic vectors of the current feature points (128), scale feature factors, main orientation factors and other feature information. The structure of Feature GCP Table is demonstrated as follows table 1.

Among those variables, Feature Scale and Main Orient are mainly used to identify the scale and direction information of GCP respectively and are two necessary parameters of the GCP location in the process of matching. Feature Descriptor is to record the characteristic description of the vector of feature control points[12]. When SIFT is applies, the vector is 128-bit. SIFT feature operator has a good scale, rotation and shift invariance[2], whose characteristic vector has uniqueness and robustness. 1pBlock can point to the image gray value preserved separately in the database and make manual observation and matching test related to gray.

2.4 Collection of feature control points

Firstly, initial reference images can choose orthophoto ones that have been corrected or be extracted from precise correction or orthophoto correction of original remote sensing images. There is need to assess those reference images and make coordinates / projection transformation so as to gain some information meeting the accuracy requirements such as geographical coordinates information, projection information and so on. The step is directly related to information on accuracy of collected control points.

SIFT features operator has a good robustness, but still some problems about it exist such as over extraction, too dense control points in the texture-intensive part and so on. After extracting feature points using SIFT from images, those related moment corner detection factors can be used to deal with unused feature control points to choose the feature points with more obvious features in order to remove points with low threshold.

To make the GCP points well-chosen, according to the demand of control points, to adopt methods of zoning choice and local suppression is to avoid over-concentration and redundancy of GCP. The existing zoning with block uniform methods is difficult to ensure the validity of extraction[8]. The relations between textural information and local feature points taken into account, the zoning method on texture characteristics will better inhibit useless information. And it is necessary to inspect and identify control points in the way of Human-Computer Interaction.

Table.1 Structure of Feature GCP Table

Type	Variable	Instruction
string	ListID	Number for GCP
double	L□B□H	Latitude and longitude ellipsoid height in the imaging center WGS84 of GCP
double	X□Y□Z	Cartesian coordinates under the imaging center WGS84of GCP
double	east, north	Coordinates of projection plane
string	CoordSyslD	Projection plane coordinate system logo
double	mx□my	Plane accuracy of GCP
double	h	High-level face
String	HeightSyslD	Logo for Department of elevation
double	mh	Elevation accuracy
LPBYTE	1pBlock	Indiractors of GCP images
Long	ImgWidth	Width of GCP images
Long	ImgHeight	Height of GCP images
Double	FeatureScale	Scale feature factors of GCP
Double	MainOrient	Main feature orientation of GCP
Double	createTime	Imaging time used for marking phase change
Vector	FeatureDescripte r	Characteristic vector of GCP
double	Lmc. Me, Hmc	Latitude and longitude ellipsoid height at the bottom edge of the mid-point GS84 of GCP
String	Timestring	Shooting time
String	Desc	Note

Finally, identify characteristics of control points, and select their surrounding neighborhood (such as 129*129 sub-window image), whose meta-data, characteristic information and image data are stored in the table of GCP of the GCP database.

As a result, the GCP database is established and gradually enriched in the process of geometric correction and eventually the complete and global coverage of GCP database is formed. The collection process is be shown in Figure 2.

III. Correction process based on GCP database

3.1 Tradition correction process

The traditional process based on feature control point database will be instructed. Firstly, try to find control points and gain images and altitude and longitude information about those points which will be stored in the GCP database[9]. Before correcting the unknown images of GCP, try to find control points within the range ,according to altitude and longitude information of four corners of those unknown control points, and identify the general positions which are obtained from projecting on those unknown points the light of their geographical coordinates.

Then, to match control point images is actually to detect automatically and match control points from unknown control point database. Finally, ensure the accuracy of control points through human-computer interaction. In addition, as for images with the same resolution and band, the accuracy of matching control points will achieve a pixel.

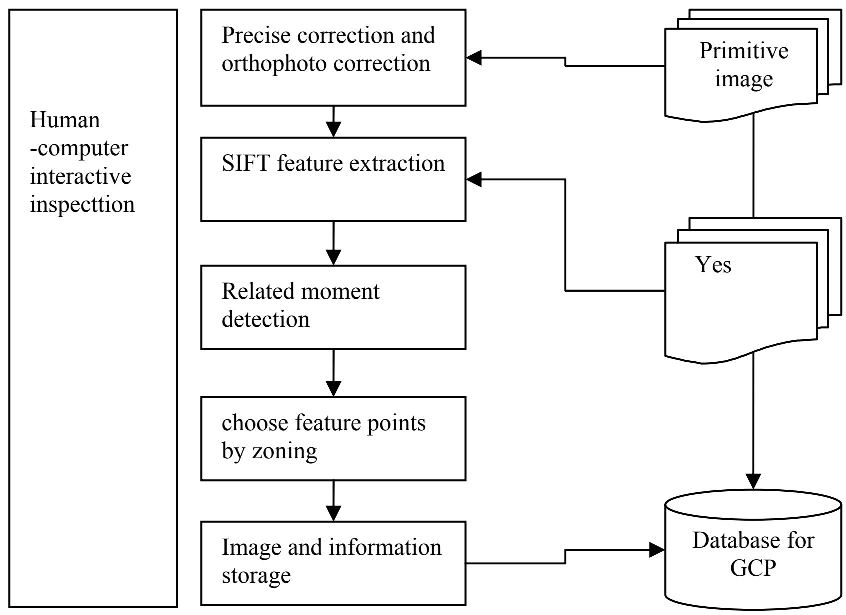

Fig.2 Collection process of feature control points.

The process is shown in Fig 3.

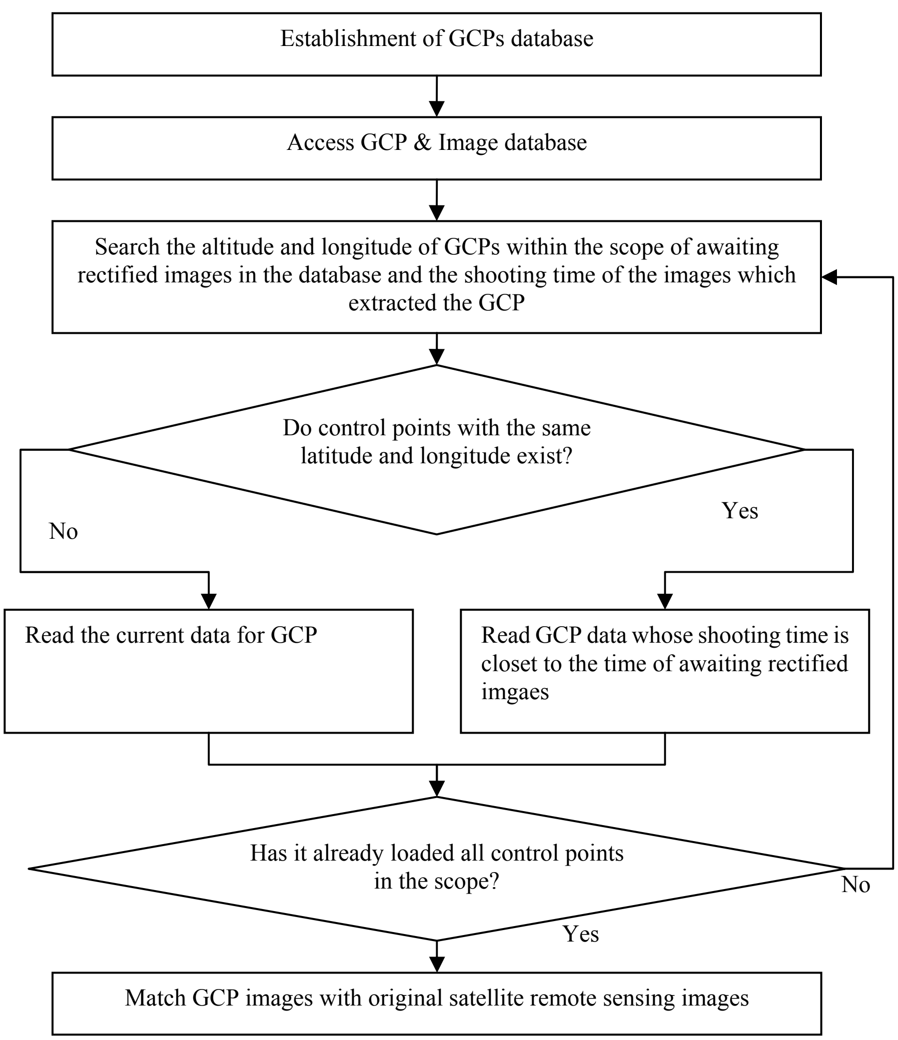

Fig.3 the flow chart of control point images database

As for an awaiting correct image, its general range of geographic location can be found. Based on this range, find the sub-database where the image locates at the beginning of this GCP database and then enter into the next level of database to make the same judgment until the lowest level of database. In this database, control points within the range can be extracted and corrected geometrically. Once a control point is extracted, its data on geographical location can be found. On the basis of its location and the range of awaiting correct remote sensing image location

The general location range of the control point can be obtained in the image. To search within this range can narrow greatly the search process of control points with the same name and improve the speed and accuracy of matching[10,11].

3.2 Application of local feature points

Based on the characteristics of control points and automatic matching algorithm with local invariant features, the GCP system can enhance its robustness on rotation, zoom, translation, image transformation and other aspects and its reliability. The flow chart will be shown in Figure 4.

The GCP processing module including acquisition, identification, application of control points and other functions can utilize the information on GCP stored in the database to identify unknown control points.

(1) Control point query

The GCP information under the management of database include its latitude and longitude and also storage and retrieval of image films. To search control points through the scope of their altitude and longitude is to find information of those points within that scope.

Due to continual updates of GCP database, a ground object may have many corresponding control points with the same name in the database. When the system is making the geometric correction of remote sensing images, it should follow the principle for finding the most suitable control point from the database: choosing the control point closest to the acquisition time of awaiting correct images.

(2) Feature extraction

After preprocessing of awaiting correct images such as blocking, enhancement and so on, the system will use SURF to extract feature descriptors and store the information on feature GCP with their feature vectors.

(3) Control point identification

Based on the altitude and longitude coordinates of four corner points of the awaiting correct images in the database, control points within this scope can be found. Then, put the control points to match with feature ones extracted from those awaiting images to identify ones of those awaiting correct images through matching and checking vectors.

(4) Matching algorithm

Matching algorithm based on local invariant features is a method combining SURF feature operator with iterative weights adjusting or random sample consensus (RANSAC algorithm). Many experiments on IKONOS images, aerial images (DMC, Digital Mapping Camera) and SPOT5 images indicate that this algorithm has very good accuracy and practicality. The accuracy can be ensured within a pixel when the scale difference is less than six times.

(5) Accuracy test and Refined calculation

After control points matching and RANSAC, relatively precise transformation model parameters can be gained. To enhance registration precision by refining the model parameters is, in light of the estimation on rough registration parameters, to match gray related GCP tiles between reference images and transformation images with rough registration to find more control points in the favorable areas and at length realize the geometric correction refinement.

4.1 SURF detector and descriptor

The advancements of the SURF algorithm with great efficiency are shown as follows :

Firstly, SURF detector use Hessian-based interest point localization for speed up. The base local feature is formed with by the eigenvalue of Hessian Matrix. For the point X in the image I, which $X = (x, y)$ and with the scale factor σ, the Hessain Matrix is Eq.(1):

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

And $L_{xx}(x, y, \sigma)$ is the Laplacian of Gaussian (LoG) of the image, which is the convolution of the Gaussian second order derivative with the image. $L_{xy}(x, y, \sigma)$ and $L_{yy}(x, y, \sigma)$ are similar.

Secondly, SURF detector use box filters(such as average filter and mean filter) approximating second order derivatives, which greatly speed up and affect litter on algorithm's precision. Further more, it is more expedient to do convolution of the Gaussian second order derivative and the transform of Haar wavelet. It is fast and only cost 4 steps include add and substract to caculate the S, which is the summed area tables of an intetral image.

Thirdly, SURF detector adopt filter pyramids. Scale spaces are usually implemented as image pyramids. The images are repeatedly smoothed with a Gaussian and subsequently sub-sampled in order to achieve a higher level of the pyramid. SURF metods steadly apply such filters of any size at exactly the same speed directly on the original image.So it cost almost same time to caculate higher level of pyramid. Therefore, the follow step to extract the interest points by Blob-like feature detector.

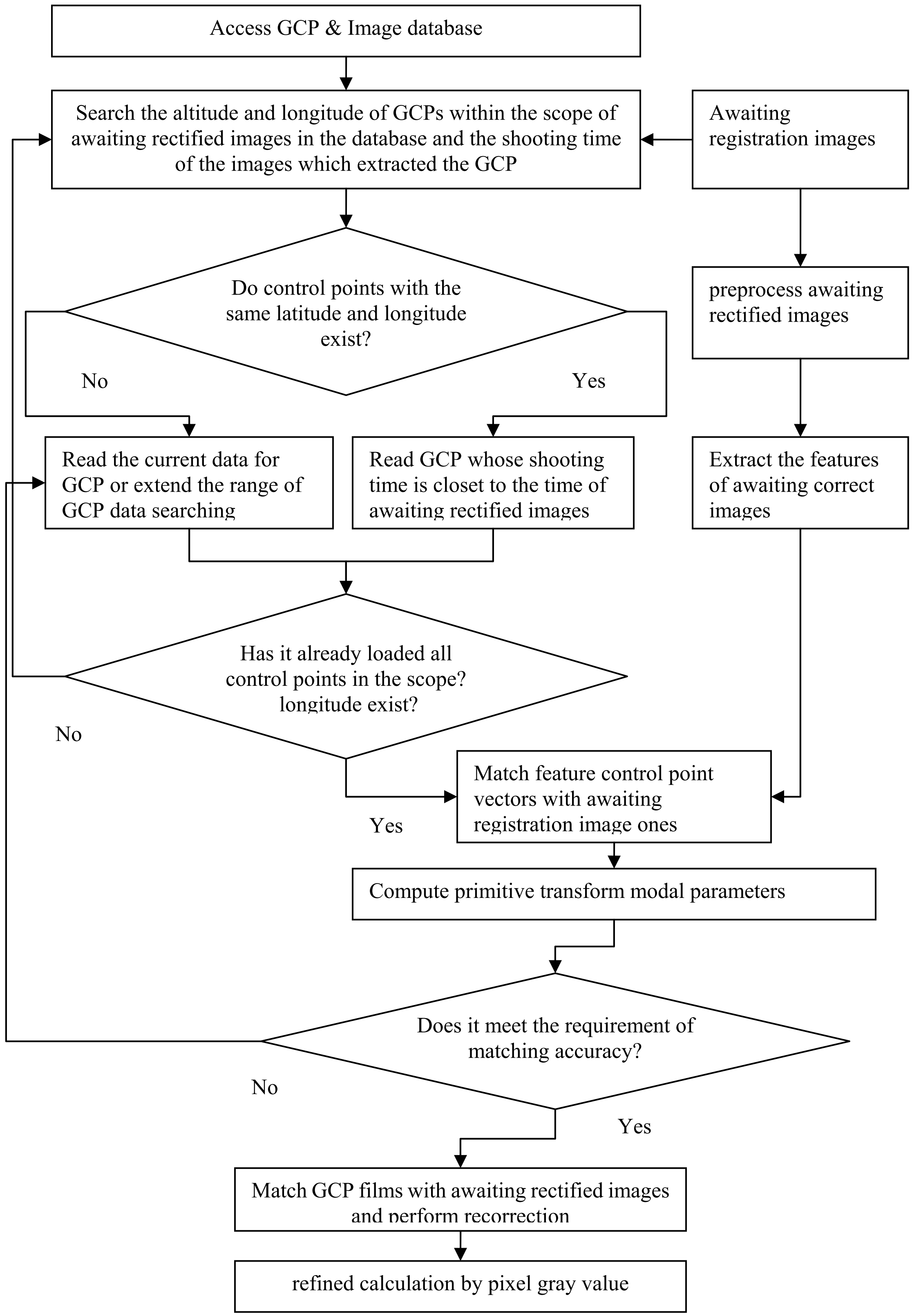

Fig.4 The flow chart of control point images database

IV. Methodology and Results

Lastly, it extract the local feature through Haar wavelet transform which makes the feature descriptor more distinctive. Transform circular neighborhood of radius 6s around the interest point with Haar wavelet to get the X response and Y response to form the feature vector. Count the vectors in the 4s around the interest point, and then select the longest vector as the dominant orientation. Finally, split the interest region up into 4 x 4 square sub-regions with 5 x 5 regularly spaced sample points inside to caculate the Haar wavelet response to compose a distinctive descriptor.

4.2 Estimate the affine modal

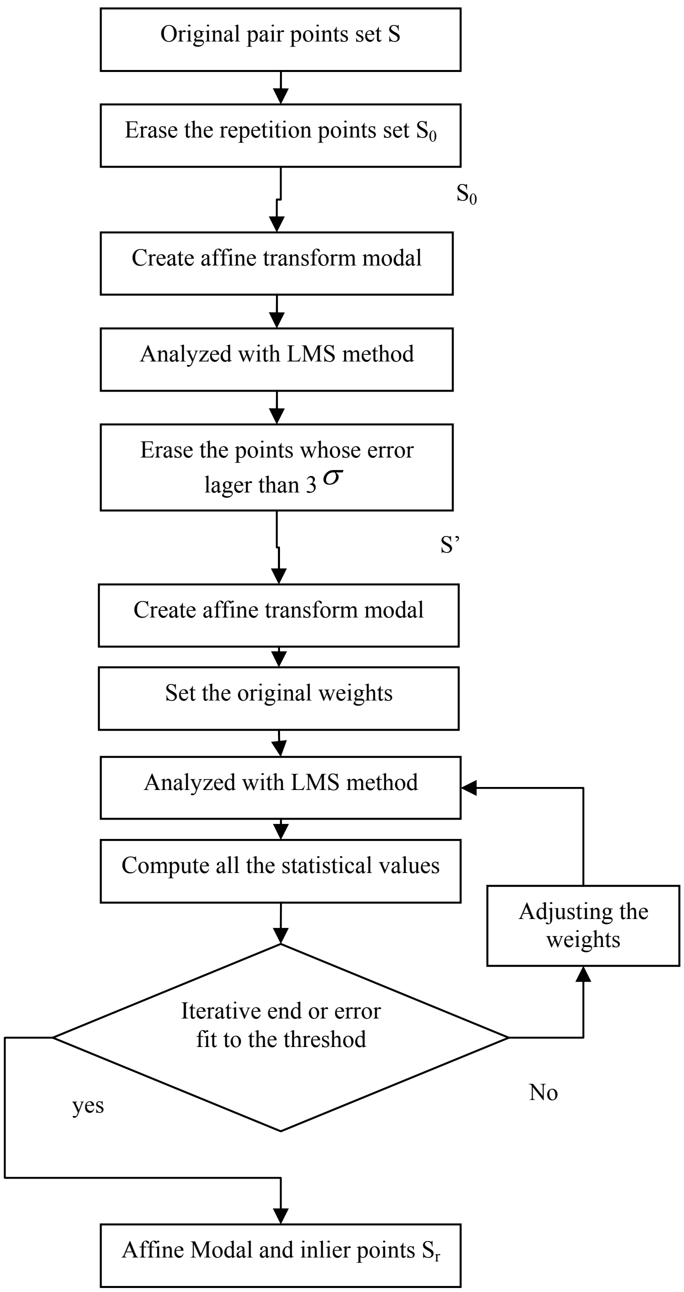

Fig.5 estimate the affine modal and detect outlier points

After obtain the original pair points, there are two methods to gain the parameters of the affine modal by modal estimating. The RANSAC is adapted in almost all the environments with the ability to find a few inlier pair points in a mount of samples[13]. But because of its complication of computing we could also use the iterative weights adjusting methods which has been apply to detect outlier points in aerophotography. In the paper we set the maximum iterative time 1000. When a point's error t(i) is larger than the threshold k, adjust the weight to 1/t(i). And relatively set the weight to 1 when the t(i) is smaller.Through above steps we adjust the weights in every iterative until no error value exceed the threshold or reach the max iterative times. Set the weight in [0.9, 1.1] as 1 and others as 0 which means it is a outlier point.At last estimate the modal using all the inlier points.

4.3 Refined calculation

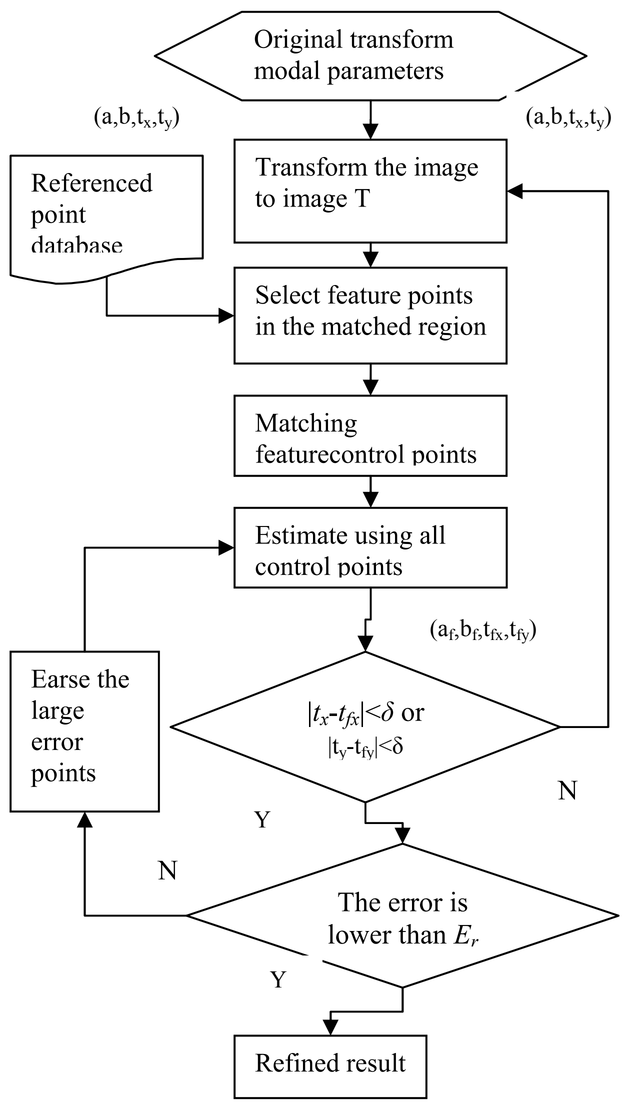

Fig.6 refine the parameters of affine transform model

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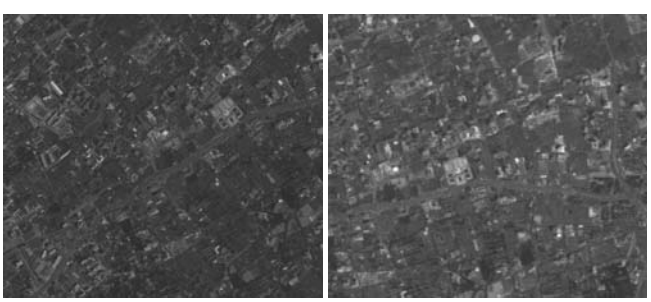
In this paper we used two pairs of High resolution image to test the matching method.

The experiment 1 include two aerial photographs, which come from the same camera sensor ,taking photo at about the same time, and taking at different viewport. Because of the different illumation, the two pictures has very large difference in color. Both pictures are 1160*840 size and 0.3 meter pixel resolution. There are farms, buildings and roads in them both.

The experiment 2 include two SPOT5 images. The reference image is panchromatic with about 5 meter pixel resolution. Correspondly, the other image is one band of the multi spectrums image with about 10 meter pixel resolution.

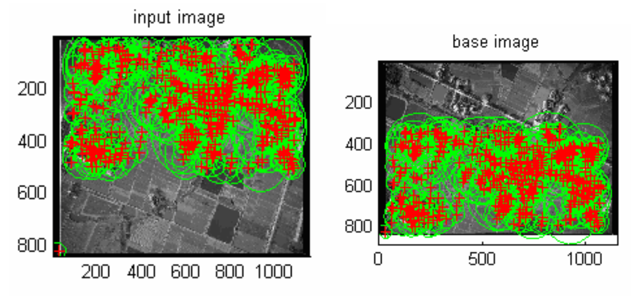
(a) aerial photographs



(b) SPOT5 images

Fig.7 High resolution test Image pairs

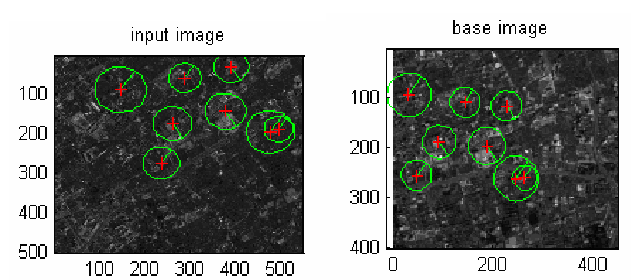
The result image shown as follows:



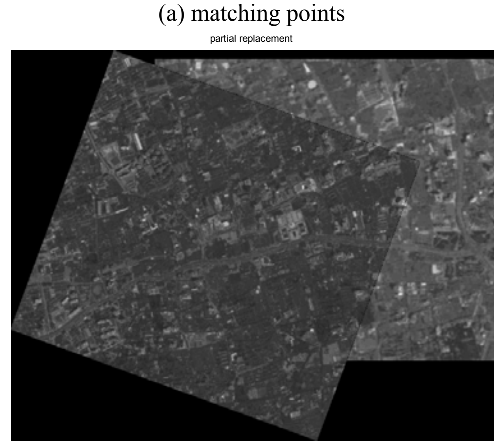
(a) matching points

(b) final registration result

Fig.8 aerial experiment result image



(a) matching points



(b) final registration result

Fig.9 final registration result

To show the validity of SURF method, we contrast it with SIFT method which used in many computer vision region.

Table.2 the compare SURF and SIFT result

Item	Experiment 1		Experiment 2	
	SURF	SIFT	SURF	SIFT
threshold	0.5	0.5	0.4	0.4
Feature points number	(1958□2405)	(7963 □ 9059)	(242 □ 250)	(1917 □ 2518)
Original pair points number	436	752	752	752
Effectual pair points number	335	640	335	335
ratio %	75.28%	85.11%	75.28%	75.28%
RMSE (pixel)	1.3364	1.3207	1.3364	1.3364
Parameters of the affine transform modal	(0.9959 □ 0.0034 □ -17.6006 □ -0.0081 □ 0.9959 □ 299.0616)	(0.999 □ 0.0035 □ -19.5275 □ -0.0093 □ 0.9988 □ 298.7168)	(0.9959 □ 0.0034 □ -17.6006 □ -0.0081 □ 0.9959 □ 299.0616)	(0.9959 □ 0.0034 □ -17.6006 □ -0.0081 □ 0.9959 □ 299.0616)

From the experiment we also find that SURF feature extraction algorithm consume less time than SIFT, and also get less effective points than the SIFT under the same requie efficiency of extraction points. So it greatly reducing the post-match search processing operations, and reducing time consumption of the algorithm. We can testify it from the table 3.

Table 3 the compare of time used by two methods

Experiment Time cosed□s□	Experiment 1		Experiment 2	
	SURF method	SIFT method	SURF method	SURF method
Feature GCP extract	1.247	3.344	0.356	1.183
Original matching	3.225	4.307	0.10	0.33
Modal estimate	15.221	18.722	0.06	0.13
Matching refined	22.089	28.177	1.73	2.48
Total time	41.782	54.550	2.246	4.123

V. Comparison and Analysis

Compared with the traditional geometric correct algorithm and the correction process based on GCP database, the database for feature control point images have the following advantages.

(1) Compared with the traditional method related gray, feature matching algorithm has better robustness and stability on registration processing of multi-source image data. Image data from different sensors have different resolutions, imaging angles and, thus it is difficult for those gray related methods to adapt. However, using SIFT based on local feature invariance can ensure stability on rotation, scale and translation and even achieve relatively higher registration precision under the condition of affine transformation.

(2) Feature control points usually possess less storage space. The experiments on image matching can demonstrate that using feature vector matching method and image- gray matching method can achieve better accuracy. Meanwhile, the feature vector can be gained through compressing and describing image characteristics, for instance, SIFT descriptor occupies only 128 bits while general image points for 65x65 or 129x129 occupy larger space. Therefore, to reduce gray-image information stored in the database can compress space. In that case, even if the number of GCP is large, it still has practical meaning.

(3) Feature control points collection from different types of sensors and different images has better independence. After extracting information on GCP and feature vectors, control points can be managed by the database and reused many times and also avoid the redundant operation on reading image data many times in the process of gray-image matching.

(4) The feature matching algorithm can deal with data with high efficiency. Some experiments have indicated that to deal with SIFT operator + RANSAC matching with size of 1300 * 1300 only takes 51.55 seconds (the algorithm using Matlab and C++ on the WinXP platform), which consumes less time than the gray-related matching algorithms between the interval sliding.

VI. Conclusion

This article discusses the process of the establishment of the feature control points database and the data structure of GCP tables in the database and a large number of precise control points can be extracted and managed through the support of the database. The automatic selection of GCP can not only ensure the quick geometric correction of a large volume of satellite remote sensing images with high accuracy but also provide a prerequisite for processing massive satellite remote sensing image with high resolution. In the process of image matching, the primary problem is the choice of matching-similarity measurement. In this paper, the author utilized the automatic matching algorithm of local invariant features based on SIFT operator, eliminate the influence of geometric deformation such as rotation, zoom, translation, etc. between control point images and original remote sensing images on matching and match automatically images with control point films from other sources. Based on this, the quick auto-correction of images can be realized.

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