Smart Rectification on Satellite images

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ABSTRACT

The mainly used technique to rectify satellite images with distortion is to develop a mathematical relationship between the pixel coordinates on the image and the corresponding points on the ground. By defining the relationship between two coordinate systems, a polynomial model is designed and various linear transformations are used. These GCP based geometric correction has performed overall plane to plane mapping. In the overall plane mapping, overall structure of a scene is considered, but local variation is discarded. The highly variant height of region is resampled with distortion in the rectified image. To solve this problem, this paper proposed the TIN-based rectification on a satellite image. The TIN based rectification is good to correct local distortion, but insufficient to reflect overall structure of one scene. So, this paper shows the experimental result and the analysis of each rectification model. It also describes the relationship GCP distribution and rectification model. We can choose a geometric correction model as the structural characteristic of a satellite image and the acquired GCP distribution.

1. Introduction

There are two points of view to correct geometric distortion of satellite images. One is a system rectification which is a process to correct distortion by analyzing causes of distortion systematically. It is good to correct all images easily in the same system if an inverse transformation of a system, the transformation from a scanned image with distortion to an original scene, is computed. But it is difficult to analyze causes of all distortions and to correct absolutely in the case of ground with high undulations. The other is a rectification with ground control points(GCPs). This is a rectification to correct distortion by defining the mapping relation mathematically between a scanned image and a base map without analysis of cause of distortion. It is useful when it is hard to analyze cause of distortion, and also advantageous to correct distorted image more accurately than system geometric correction if GCPs are collected accurately. But the rectification with GCPs is dependent on choice of GCPs. This paper introduces a rectification method with GCPs and analyzes experimental. Plane level correction has been used for the rectification with GCPs, but it is hard to correct some regions full of ups and downs. To improve these defects, TIN based rectification is proposed in this paper. Plane geometric correction method is described in the second section and TIN based geometric correction method is introduced in the third section and result of each method is numerically analyzed in the fourth section. Finally we conclude and introduce future work.

2. Plane Geometric Correction

Plane geometric correction is a method to reproduce a corrected image by defining the mathematical relationship between GCPs and its corresponding image control points(ICPs). Suppose that a GCP is a point on X-Y plane and a ICP is a point on u-v plane. The mapping relation between GCP and ICP can be defined by some transformations such as affine, conformal, pseudo-affine, projective transformation and n-th order polynomial for defining mapping relation of control points [1][2][3][4][5]. A mapping relation is represented like eq.(1) by affine transformation.

$$\begin{aligned} u &= a_1 x + b_1 y + c_1 \\ v &= a_2 x + b_2 y + c_2 \end{aligned} \tag{1}$$

Eq.(1) needs three or more pairs of GCP and ICP for six affine parameters. Conformal transformation consists of four parameters like eq.(2) and needs two or more pairs of GCP and ICP.

$$\begin{aligned} u &= ax + by + c \\ v &= -bx + ay + d \end{aligned} \tag{2}$$

Pseudo-affine transformation is a bilinear form of affine transformation, represents mapping relation with eight parameters like eq.(3) and requires four or more pairs of GCP and ICP for pseudo-affine parameters.

$$\begin{aligned} u &= a_1 x + b_1 y + c_1 xy + d_1 \\ v &= a_2 x + b_2 y + c_2 xy + d_2 \end{aligned} \tag{3}$$

Projective transformation is more general than above transformations and defines mapping relation non-linearly. It uses eight parameters and needs four or more pairs of GCP and ICP as shown by eq.(4).

$$\begin{aligned} u &= (a_1 x + b_1 y + c_1)/(a_3 x + b_3 y + 1) \\ v &= (a_2 x + b_2 y + c_2)/(a_3 x + b_3 y + 1) \end{aligned} \tag{4}$$

Eq.(5) is a linear form of projective transformation and also comprised of eight parameters.

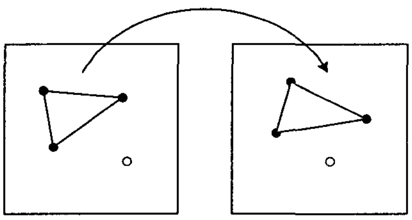
$$\begin{aligned} u &= a_1 x + b_1 y + c_1 - a_3 xu - b_3 yu \\ v &= a_2 x + b_2 y + c_2 - a_3 xv - b_3 yv \end{aligned} \tag{5}$$

Eq.(5) needs four or more pairs of GCP and ICP for computing the parameters. Finally, most widely used transformation for geometric correction is a method to get parameters by defining mapping relation with n-th order polynomial, a form of eq.(6), and requires n/2 or more pairs of GCP and ICP.

$$u = c_1 + \sum_{j=0}^{n} \sum_{k=0}^{n-j} a_{jk} x^j y^k$$
$$v = c_2 + \sum_{j=0}^{n} \sum_{k=0}^{n-j} b_{jk} x^j y^k \quad (6)$$

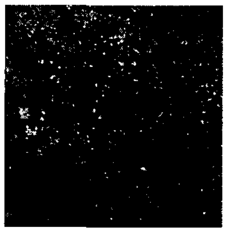
3. TIN based Geometric Correction

Transformation parameters under plane geometric correction are computed by least-square method using pairs of control points more than required. It is possible that some high variable region affects overall transformation and that distortion of the local region is not corrected well. So, we construct TIN and apply transformations described at second section to each TIN. Every TIN consists of three GCPs. So, transformations with seven or more parameters- pseudo-affine, projective transformation and the second or higher order polynomial cannot be used for TIN based rectification. As shown by figure 1, transformation parameters are computed at TIN level.



<fig1. TIN based geometric correction>

A TIN consisting of three GCPs is corresponded to a triangular patch comprised of three ICPs. Each ICP is corresponded to each GCP. Figure 2 is a IKONOS image of Daejeon and figure 3 is a resampled image through affine transformation TIN by TIN. Figure 4 shows a resampled image under plane geometric correction using affine transformation.



<fig2. IKONOS image>

<Fig 3. a resampled image by TIN based rectification>

<fig4. a resampled image by plane rectification>

4. Result analysis

As each pair of GCP and ICP, GCP is differently mapped to ICP and the difference is wide at the region full of ups and down of ground. So, the plane rectification by applying least-square method to all pairs of GCP and ICP makes error in the correction of images geometrically for high variable region. But we cannot guarantee with only resampled image like figure 3 that TIN based geometric correction complements limit of plane geometric correction if GCPs are not collected over various regions with various height. To verify that TIN based geometric correction complements defects of plane geometric correction, we tried numerical approach. We used affine transformation to compare TIN based rectification with plane rectification and computed variance of each pair of GCP and ICP and that of each affine parameter. Figure 2 is used for experiment. Table 1 and 2 show respectively GCP and variance list of pairs of GCP and ICP under affine transformation in plane rectification.

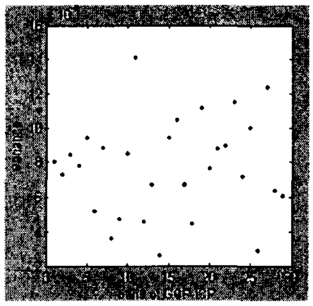
ID	Ground Control Point(GCP)		
	x	y	z
1	3.528327e+5	4.024984e+6	6.882000e+1
2	3.552423e+5	4.024802e+6	6.888000e+1
3	3.569202e+5	4.024683e+6	6.712000e+1
4	3.509735e+5	4.023604e+6	7.342000e+1
5	3.591581e+5	4.023168e+6	8.596000e+1
6	3.514869e+5	4.020892e+6	7.440000e+1
7	3.503315e+5	4.018708e+6	8.877000e+1
8	3.541701e+5	4.018823e+6	1.043800e+2
9	3.563099e+5	4.017989e+6	1.510400e+2
10	3.561400e+5	4.015916e+6	9.622000e+1
11	3.503676e+5	4.015972e+6	8.512000e+1
12	3.572693e+5	4.021847e+6	8.453000e+1
13	3.508509e+5	4.022260e+6	7.671000e+1
14	3.550191e+5	4.020328e+6	7.211000e+1
15	3.583416e+5	4.024119e+6	8.100000e+1
16	3.585379e+5	4.016097e+6	1.498900e+2
17	3.568769e+5	4.023851e+6	6.334000e+1
18	3.522042e+5	4.019890e+6	7.649000e+1
19	3.568430e+5	4.015051e+6	1.058200e+2
20	3.592710e+5	4.021218e+6	7.799000e+1
21	3.597402e+5	4.018934e+6	1.310600e+2
22	3.496534e+5	4.021475e+6	7.867000e+1
23	3.598908e+5	4.016884e+6	1.353800e+2
24	3.505233e+5	4.020185e+6	1.018100e+2
25	3.508803e+5	4.024827e+6	7.196000e+1
26	3.554730e+5	4.021519e+6	6.898000e+1
27	3.543366e+5	4.014584e+6	1.184800e+2
28	3.579156e+5	4.022690e+6	6.853000e+1
29	3.516403e+5	4.023012e+6	7.038000e+1

<table 1. GCP list>

ID	Variance	ID	Variance
1	7.996808e-8	16	1.041630e-7
2	7.254454e-8	17	6.670355e-8
3	8.395155e-8	18	4.439001e-8
4	7.808945e-8	19	1.110862e-7
5	9.419264e-8	20	7.622968e-8
6	5.189482e-8	21	8.769915e-8
7	8.811029e-8	22	8.920290e-8
8	3.576810e-8	23	1.148567e-7
9	4.730126e-8	24	7.136881e-8
10	8.475041e-8	25	1.000656e-7
11	1.407592e-7	26	2.912913e-8
12	4.584071e-8	27	1.231981e-7
13	6.685885e-8	28	6.356998e-8
14	2.598235e-8	29	6.060172e-8
15	9.427052e-8	Total variance	7.441824e-7

<table 2. variance list>

Figure 5 is a graph of table 2 and shows difference of variances of pairs of GCP and ICP. Variance of each pair of them is slightly different but control points of id 11, id 26 and id 27 in the list of table 2 are widely different from variances of others. This implies that the distribution of variance of ICPs mapped to GPCs by affine transformation affects on accuracy and reliability of affine parameters and that errors increase under plane rectification.



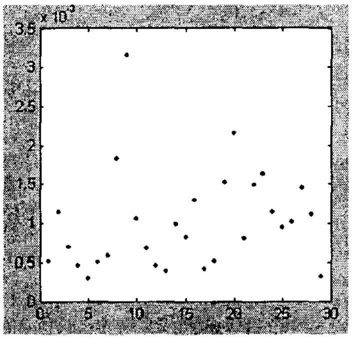
<fig.5 variance of ICPs mapped to GCPs by affine transformation under plane rectification>

Affine parameters under plane rectification are listed in the table 3. Figure 6 shows difference value between

GCPs and coordinates computed by inverse transformation of corresponding ICPs with affine parameters of table 3.

Parameter	Value
a1	9.937952e-001
b1	-1.393752e-002
c1	-3.121805e-003
a2	6.890367e-002
b2	-9.898057e-001
c2	1.564162e-002

<table 3. Affine parameter>



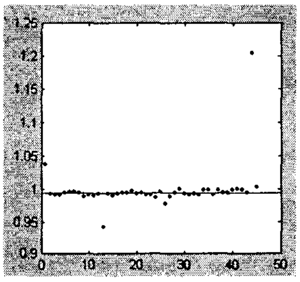
<Fig. 6 difference between GCPs and coordinates computed by inverse transformation>

Figure 6 shows that the difference of variance of control points affects reliability of plane rectification method. If the number of pairs of GCP and ICP is more than that of control points required for computing affine parameters, we generally get statistical value with least-square method. In the case that variance of control points is considerably different from each other, it causes to compute parameters with error and satellite images are corrected with distortion. But without using all pairs of control points, we get unique set of parameters TIN by TIN. Table 4 is a list of TINs constructed with GCPs. From the mapping relation between TIN and triangular patch, unique set of affine parameters is computed and the coordinate system of transformed triangular patch keeps the same to the coordinate system of TIN.

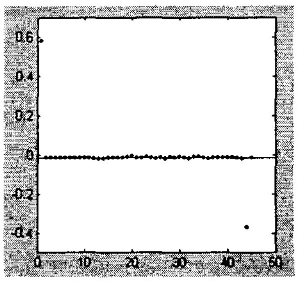
TIN ID	GCP ID	TIN ID	GCP ID
1	1 2 3	23	7 8 18
2	1 2 26	24	7 11 22
3	1 4 25	25	7 18 24
4	1 4 29	26	7 22 24
5	1 26 29	27	8 9 10
6	2 3 17	28	8 9 14
7	2 17 26	29	8 10 27
8	3 15 17	30	8 14 18
9	4 13 22	31	8 27 11
10	4 13 29	32	9 10 16
11	4 22 25	33	9 12 14
12	5 15 28	34	9 12 21
13	5 20 21	35	9 16 21
14	5 20 28	36	10 16 19
15	6 13 22	37	10 19 27
16	6 13 29	38	12 14 26
17	6 14 18	39	12 17 26
18	6 14 26	40	12 17 28
19	6 18 24	41	12 20 21
20	6 22 24	42	12 20 28
21	6 26 29	43	15 17 28
22	7 8 11	44	16 19 23
		45	16 21 23

<table 4. TIN List>

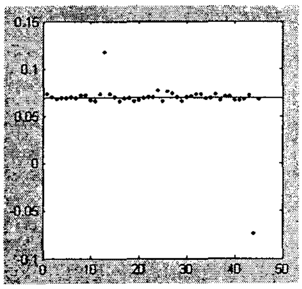
Figures 7 to 12 are graphs of affine parameters under TIN based rectification. At each figure, blue points are values of affine parameters under TIN based rectification and red lines are values of affine parameters under plane rectification. Figure 7, 8, 9, 10, 11 and 12 are graphs of parameter a1, b1, a2, b2, c1 and c2 respectively.



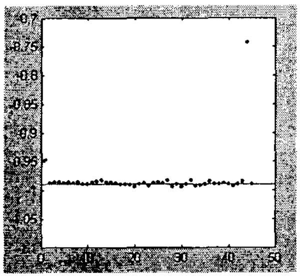
<fig.7 parameter a1>



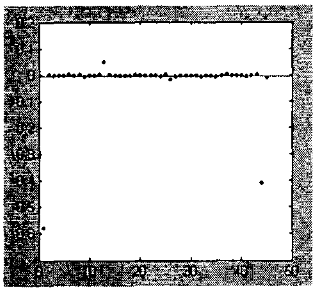
< fig.8 parameter b1>



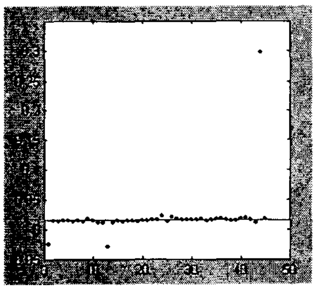
<fig.9 parameter a2>



<fig.10 parameter b2>



< Fig.11 parameter c1>



< fig.12 parameter c2>

In each distribution of parameters, TIN 44 with the widely difference against other TINs consists of GCPs of id 16, id 19 and id 23 and has large variance under plane rectification. TIN 14 and TIN 29 also have wide difference against other TINs consisting of GCPs with large variance, because the region with high undulation is constructed to a TIN. This means higher undulate, more error. It also means that TIN based rectification depends on the method of TIN construction.

6. Conclusion

We introduced TIN based rectification for decreasing accumulative errors over all pairs of GCP and ICP. Although overall error of image is decreased by constructing TIN with GCPs and transforming TIN by TIN, it is dependent on the method of constructing TIN. It is also controlled by accuracy of mapping relation between GCP and ICP. We have further work with respect to these problem and need to research continuously.

6. Reference

[1] http://ceeserver.cee.cornell.edu/wdp2/cee615/Monograph/615_04_GeomCorrect_rev01.pdf

[2] V.Vorrawat, F.Cheevasuvit, K.Dejihan, S.Mitatha and A.Somboonkaew, "Geometric correction by GPS", 18th Asian Conference on Remote Sensing, October 20-24, 1997

[3] http://www.ffp.csiro.au/nfm/mdp/bbproj/georect.htm

[4] http://deathstar.rutgers.edu/courses/remsens/remsensing5/index.htm.

[5] http://aria.arizona.edu/courses/tutorials/html/geometric.html