ACQUISITION METHOD OF GROUND CONTROL POINTS FOR HIGH RESOLUTION SATELLITE IMAGERY

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ABSTRACT:
As for geometric correction of high resolution satellite imagery, acquisition of ground control points (GCPs) is important. In this study, acquisition methods of GCPs were evaluated. In this study, IKONOS imagery was used as high resolution satellite imagery. Method of geometric correction was selected 3D affine transform. Firstly, 1:2500 map and fast static GPS surveying were used for acquisition of GCPs. Result showed GCPs acquired from the map did not have enough accuracy. On the other hand, GCPs acquired by GPS were able to be acquired less than 1m correction error, and it turns out that GPS had enough accuracy. Next, image matching was carried out using aerial photograph to acquire GCPs. In the image matching, correlation coefficients were calculated. As template image, small bridge, road shape and painting character were efficient for image matching. Therefore, if true ortho photography was prepared using the laser scanner or three lines sensor, it may become possible to carry out geometric correction.

1. INTRODUCTION

High resolution satellite imageries as less than 1m resolution are used in many fields. For example, updating existing map, land use mapping, urban planning, disaster monitoring, and so on. However acquisition of GCPs has some problems for geometric correction in high resolution satellite imagery. For acquisition of GCPs , map of scale 1:2500 might be easily. That map was published in every urban area in Japan. However, position of the road has fuzzy boundary which is sidewalk etc. Moreover, since satellite imagery is generated by central projection, corner of building on the ground is difficult to interpret. Therefore, extraction of GCPs from the map will be difficult.

2. OBJECTIVES

This study aim is evaluating the acquisition method of GCPs for geometric correction of high resolution satellite imagery using three methods as follows:

GCPs were acquired from maps. Used maps were generated for urban planning, which is scale 1:2500. These maps are digitized vector data.

GCPs were acquired by field surveying using GPS. As GPS surveying, fast static method with 1 cycle was applied. Survey period was about 20 minutes in each point, and record interval was every 30 seconds.

Image matching was carried out using aerial photography. Acquisition date of used aerial photography is Oct 10, 1998.

3. HIGH RESOLUTION SATELLITE IMAGRY

In this study, IKONOS was used as high resolution satellite imagery (Table 1). It was the digital-geo image which was corrected distortion by the roundness of the earth. Test area is selected in Tosayamada, Kochi prefecture, JAPAN. Image area size is about 11km x 11km. There are several small town, deep forest, wide river, many farm lands, port, and so on. There is no skyscraper.

4. METHODOLOGY

Method of geometric correction was used 3D affine transform (Eq.1). 3D affine transform can be adapted for geometric correction of high resolution satellite imagery by Dowman [(1)](I Dowman, 2000), Yamakawa [(3)](T Yamakawa, 2002), Kadota [(4)](T Kadota, 2002)

Item	Detail
Cross Scan	0.86 m
Along Scan	0.84 m
Scan Direction	0°
Nominal Collection Azimuth	263.9600°
Nominal Collection Elevation	76.68608°
Acquisition Date/Time	2000/6/15
Photography Area	Tosayamada Kochi JAPAN
Area (km^2)	134.848
Product Level	Digital-Geo Image
Sensor Type	Pan-Sharpen (4 Bands)
Map Projective Method	Transverse Mercator
Ellipsoid	Bessel
Datum	Tokyo

Table 1. Specification of Used IKONOS

$$u = a_1x + a_2y + a_3z + a_4$$
$$v = b_1x + b_2y + b_3z + b_4 \qquad \text{(Eq.1)}$$

u, v : Image Coordinates
x, y, z : Ground Coordinates
a_1-a_4, b_1-b_4 : Unknown Coefficient

At first, unknown coefficients were calculated by least squares method using ground coordinates (x,y,z) and IKONOS imagery coordinates (u,v). Accuracy of ground coordinates was evaluated. Then root mean square errors were calculated using image coordinates.

5. RESULT OF GCPs ACQUISITION FROM 1:2500 MAP

From the map, edge and center of the bridge and intersection of the road were selected as GCPs. Numbers of ground coordinates were 38 points, 8 points were used for GCPs and 30 points were used for verification points. Table 2 shows root mean square errors of map by 3D affine transform. The unit is displayed by meter. In the case of GCPs, root mean square errors showed less than 1m. On the other hand, in the case of verification points, root mean square errors showed over 1m. Figure 1 shows error vectors of geometric correction on verification points. Scales of error vectors were expanded by 200 times. It turns out that northwest area of error vectors had tendency to be large. Figure 2 shows sample of map distortion on satellite image. The map was overlaid on IKONOS satellite imagery which carried out geometric correction, and chosen the place where error vectors were large. Therefore, 1:2500 map did not have enough accuracy.

Table2. Root Mean Square Errors of Map by 3D Affine

RMSE	MAP	
	u	v
Ground Control Points (m)	0.5832	0.6371
Verification Points (m)	1.2155	2.6356

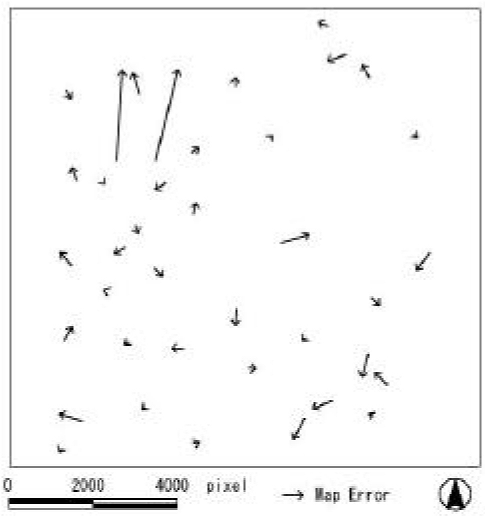

Figure 1. Error Vectors of Geometric Correction Using Map

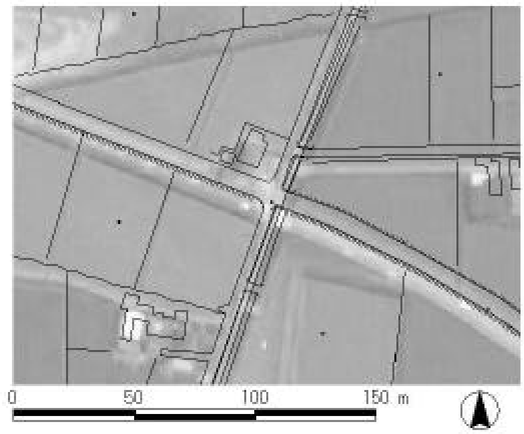

Figure 2. Sample of Map Distortion on Geo-Corrected Satellite Image

6. RESULT OF GCPs ACQUISITION BY GPS

GCPs were selected as the place where it can be surveyed safely and easily in field surveying. For example, small bridge, painting object on parking lot and footpath of field. Numbers of acquired ground coordinates were 43 points, 8 points were used for GCPs and 35 points were used for verification points. Table 3 shows root mean square errors of GPS by 3D affine transform. The unit is displayed by meter. Root mean square errors of GPS are less than 1m. Figure 3 shows error vectors of geometric correction on verification points. Scales of error vectors were expanded by 200 times. Error vectors on almost verification points showed very small. Especially, error on "v" axis showed larger. And error vector in north area had large. As this reason, the place is in the deep forest on the mountain. Figure 4 shows sample of map distortion on satellite image. Though, this image was chosen the place where southwest area error vector is large, map was hardly shifted.

Table3. Root Mean Square Errors of GPS by 3D Affine Transform

RMSE	GPS	
	u	v
Ground Control Points (m)	0.5866	0.3716
Verification Points (m)	0.9958	0.5562

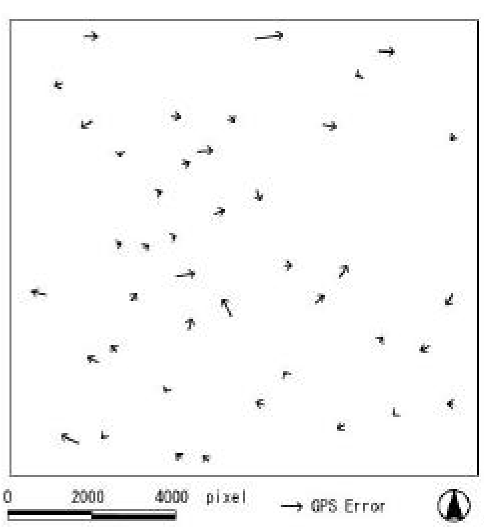

Figure 3. Error Vectors of Geometric Correction Using GPS

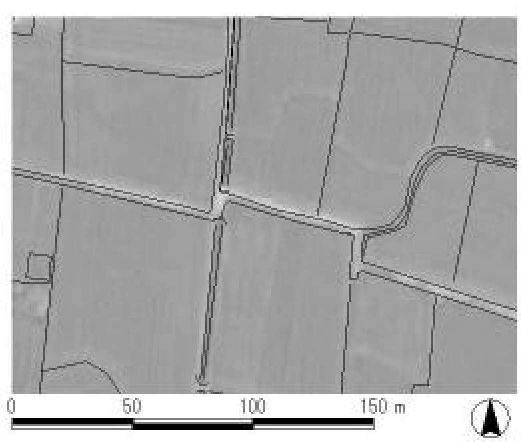

Figure 4. Sample of Map Distortion on Geo-Corrected Satellite Image

7. POSSIBILITY OF IMAGE MATCHING WITH AERIAL PHOTOGRAPHY

Acquisition of ground coordinates using 1:2500 map had made low accuracy. Acquisition using GPS had enough accuracy. However, GPS surveying needs much time and labor. By the way, aerial photography is expected to acquire ground coordinate by using image matching. Therefore, the possibility of image matching was discussed in this chapter.

7.1 Method of Image Matching

Firstly, expected ground objects for image matching were selected. The selected objects were big bridge, small bridge, road shape (T-intersection, Y-intersection, S-curve), pool, painting object on the road. Spatial resolution of aerial photography is 0.5m. Template image for image matching was made from aerial photography. Compared with IKONOS imagery, some roads and fields on aerial photography had difference because there is time lag about 2 years.

The template image was scarred calculating correlation coefficient. And coordinate of the highest correlation were selected. The correlation coefficient was calculated each RGB and added three of them. Figure 5, 6, 7 and 8 show sample images used for image matching.

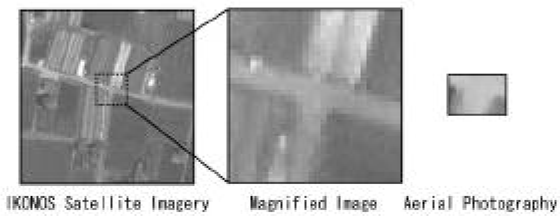

Figure 5. Matching Image of Road (T-Intersection)

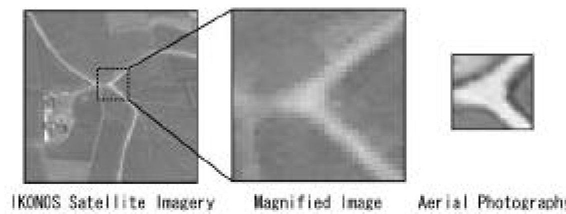

Figure6. Matching Image of Road (Y-Intersection)

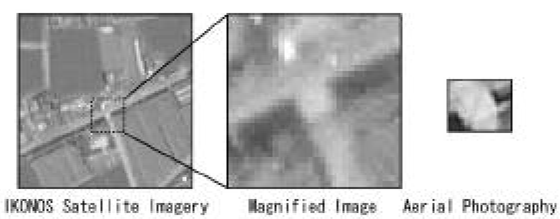

Figure 7. Matching Image of Small Bridge

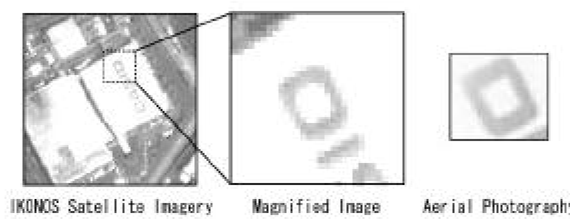

Figure 8. Matching Image of Painting Object

7.2 Result

Table 3 shows result of image matching. Result was classified into three categories with “Good”, “Fair” and “Poor”. “Good” means efficient as GCPs. “Fair” means difficult as GCPs. “Poor” means impossible to use. The small bridge had the highest correlation. This reason is that position of small bridge had clear. As opposed to it, big bridge had shadows and edge of bridge did not have clear, so it was hard to match. The second high correlation indicated on road shape. However, Y-intersection and S-curve have low correlation compared with T-intersection. It is thought that amount of vegetation of IKONOS satellite imagery and aerial photograph was different. Pool was not matched. The reflection of water surface of IKONOS imagery was different from water surface of aerial photography.

Ground Object	Correlation Coefficient	R (Correlation Coefficient)	G (Correlation Coefficient)	B(Correlation Coefficient)	Comment	Result
Bridge	1.5555	0.4923	0.4934	0.5698	By the satellite imagery, the edge of bridge was not clear. Aerial photography, there was shadow.	Fair
Small Bridge	2.5794	0.8659	0.8487	0.8649	Its position was clear and it seldom influenced of the shadow.	Good
Road Shape (T-Intersection)	2.5356	0.8009	0.8422	0.8924	Road Shape was clear and it was easy to match.	Good
Road Shape (Y-Intersection)	2.2985	0.7383	0.7751	0.7852	It was easy to match. However, it was thought that the difference in the amount of vegetation of satellite imagery and aerial photograph lowered the correlation coefficient.	Good
Road Shape (S-Curve)	2.2548	0.6994	0.7664	0.7890	It had matched. However, this was also considered that the difference in the amount of vegetation had affected the correlation coefficient.	Good
Pool	1.2388	0.4087	0.4213	0.4088	Matching was difficult. The reflection of water surface on satellite imagery was different from the water surface on aerial photography.	Poor
Painting Object (Line)	2.0206	0.6636	0.6641	0.6929	There were not many clear lines.	Fair
Painting Object (Character)	1.9936	0.8624	0.8260	0.3052	It was easy to match a big character.	Good

Table 4. Result of Image Matching

Originally template image must be generated from ortho photography. In this study, ortho photography was not created yet. If ortho photography can be created, it may become possible to carry out geometric correction.

8. CONCLUSIONS

Accuracy verification of GCPs from 1:2500 map and GPS was carried out by 3D affine transform. GCPs from the map had larger errors, the map did not have enough accuracy. Since GCPs from GPS had less than 1m errors, geometric correction of high resolution satellite imagery can be adapted in enough accuracy by using GPS.

When aerial photography of 0.5m resolution was used for acquisition of GCPs by image matching, small bridge, road shape and painting character were able to use as template image. In this study, ortho photography was not created. True ortho photography created using the laser scanner or three lines sensor is expected to acquire GCPs .

9. REFERENCES

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