EXPERIMENTAL STUDY OF DIRECT GEOREFERENCING SYSTEM (DGS) FOR LARGE-SCALE MAPPING

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ABSTRACT:

Presently for the orthophoto projects and small-scale mapping (e.g., 1:2,500) the aerial triangulation is no longer essential while Direct Georeferencing System (DGS) is available as a complementary technique. Though, it is possible to achieve sufficient accuracy by doing simultaneous block adjustment with minimum number of the ground control points, in some cases there are insufficient inaccuracies of a direct georeferencing in large scale mapping of 1/1000～1/500. It is very cost effective by reducing the expenses for the ground surveying. Further, quality control and accuracy improvement of the photo block are promising with the DGS. In this paper, the investigation of the experimental accuracy of simultaneous bundle adjustment for large-scale mapping is reported. Since 2002, the PASCO Corporation has introduced two sets of APPLANIX POS/AV for its two units of aerial cameras (RC30) and we have conducted several accuracy investigations. According to the specification of product, the accuracy levels of direct georeferencing system after post-processing are 5 - 30 cm for the position; 0.005 deg for roll and pitch; and 0.008 deg for heading angle in case of high-end system. As the Geoid model is also required to transform it from ellipsoidal height to orthometric height (above mean sea level), and to always guarantee the accuracy level of large scale mapping, it was considered that the simultaneous block adjustment is essential for 1:1000 – 1:500 scale mapping. Since bundle adjustment improves block geometry, it seems that the middle class DGS is accurate enough. In this paper we present the results of the accuracy evaluation using APPLANIX POS AV/DG 310. The number and configuration of ground control points were also considered.

1. INTRODUCTION

Accuracy evaluation of direct georeferencing system has been carried out recently utilizing high-end DGS APPLANIX's POS AV 510 and mapping project specification including QC method has been established. To achieve accuracy level of large scale mapping e.g.1/500, simultaneous block adjustment is most effective methodology. Since bundle adjustment improves block geometry, it seems that the middle class of DGS can be accurate enough. The main purpose of this practical study is to evaluate accuracy level of simultaneous bundle adjustment using middle class DGS APPLANIX's POS AV 310.

Table 1 shows the specifications of POS AV 310 and 510. The specifications of the IMUs are different for 310 and 510. In this study, we evaluated 310

	POS AV/DG 310	POS AV/DG 510
Absolute accuracy (Post processed)		
Position [1](m)	0.05－0.30	0.05－0.30
Velocity (m/sec)	0.0075	0.005
Roll & Pitch (deg)	0.013	0.005
Heading (deg)	0.035	0.008
Relative accuracy		
Noise (deg/sqrt(hr))	0.15	0.02
Drift [2] (deg/hr)	0.5	0.1

1 For typical mission profiles.
2 Attitude will drift at this rate up to a maximum error defined by absolute accuracy.

Table 1. POS AV Specifications

Both 510 and 310 have same GPS as position sensor. Table 2 shows the influence of each rotation angles 0.013 deg and 0.035 deg on the ground if 150mm lens is used. The influence of the heading values were located near the fiducial mark.

	Photo scale 1/4,000 (AGD:600m)	Photo scale 1/8,000 (AGD:1,200m)
Roll & Pitch (m)	0.14	0.27
Heading (m)	0.37	0.73

Table 2. Influence of rotation elements

Actually, other errors, e.g., GPS positioning error, photo measurement error are propagated. Required map accuracy of 1/500 scale map in Japan is regulated at the standard deviation of 0.25m for both planimetric and height. In this case, exterior orientation parameters provided by DGS is sometimes not accurate enough and simultaneous adjustment can be needed to improve block accuracy.

2. PRACTICAL STUDY

2.1 Outline of practical study

In this study, accuracy evaluation was done by comparing the coordinates of check points observed in the image models using different approaches. Result of 4GCPs block, 1 GCP and also non-GCP cases were compared. Misalignment value between the camera coordinate system and IMU coordinate system is usually adjusted before project as boresight calibration. In this study, simultaneous misalignment adjustment was also evaluated together with datum shift estimation.

2.2 Test block specification

Specification of the test block and GCP/CHEK point configuration are shown in Table 3 and Figure 4.

Test site	Toyonaka City, Osaka	
Photo scale	1/4,000	
Camera type	RC30 f ＝153.221	
Strip number	Normal 10 strips	Cross 2 strips
Photo number	17 x 10=170	19 x 2=38
GCP/CHCK pts	424 points	

Table 3. Test block specification

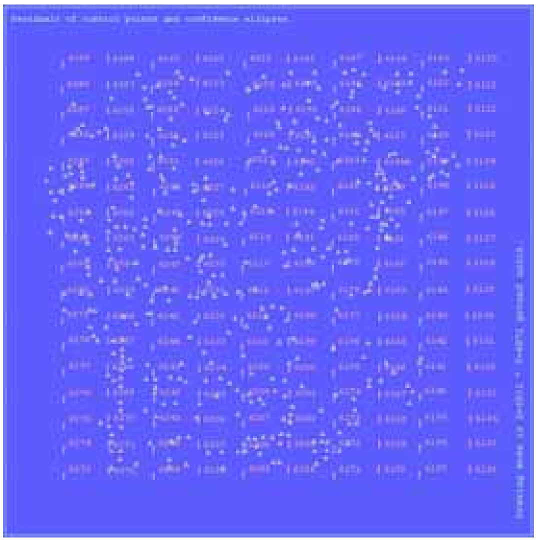

Figure 4. Configuration of GCP/CHEK points.

The test site is located at Toyonaka City of the Osaka Prefecture. Accurate and well-distributed GCPs are available throughout the city. Almost all GCPs lie on the manhole covers. The size of the manhole cover is about 40cm x 40cm square shape and the height difference from GCP to cover is also measured. This cover can be identified and observed easily in the image model. Highly accurate GCP coordinates were provided by Toyonaka City Office.

2.3 Post processing result of direct georeferencing

Post processing of direct georeferncing data was carried out using APPLANIX POSPAC software. This software package consists of data extraction, Kinematic GPS analysis, best estimation of trajectory and estimation of exterior orientation parameters. Figure 5 shows trajectory of this mission. An interval of 1 sec of the permanent GPS station was used as reference station. The maximum distance from reference station to photo station is about 11 km. The photographs at 1/4,000 and 1/8,000 scales were captured during this photo acquisition mission. Additionally, there is a domestic airport located near this site and the flight mission took 5 hours.

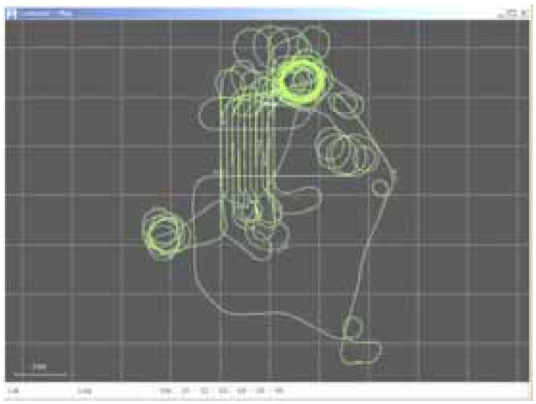

Figure 5. Trajectory of photo mission

Figure 6 shows the plot of quality factor as one of indicator of quality control. The Y-axis is a quality factor (1:Fix solution, 2: stable float solution, 3:converged float solution, 4:Less than DGPS). There are a few float solution parts but the relatively stable solution was obtained throughout flight mission. Figure 7 shows standard deviation of positions derived from Kinematic GPS solution. It is around 5cm for the entire part. Figure 8 shows residuals of forward/reverse (time related) of Kinematic GPS solution. It is also less than 5cm. It was noticed that a good and stable solution is achievable

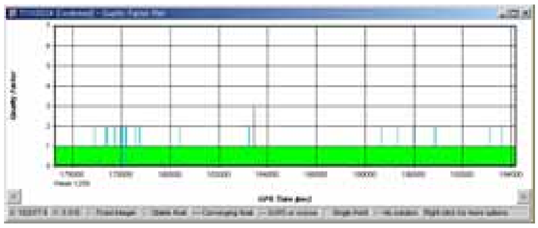

Figure 6. Quality factor

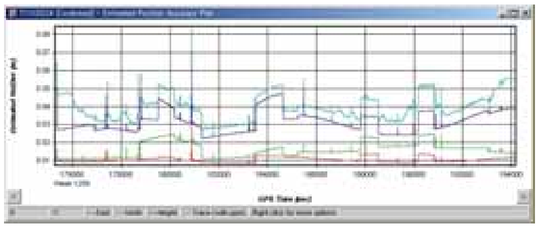

Figure 7. Standard deviation

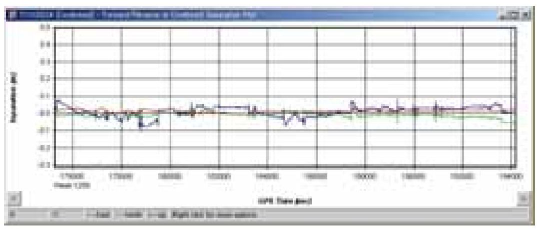

Figure 8. Residuals between FWD/REV solution

2.4 Automatic tie point extraction and GCP/CHEK observation

Captured photos were scanned by Leica's DSW500 at 20 μm resolution. Automatic tie point extraction was carried out using

ORIMA APM module consequently. The exterior orientation parameters produced by the DGS was used as initial value during this process. The tie point pattern of 11 x 11 grid was used. GCPs and check points were observed manually and pre-adjustment was carried out to reject the blunders. Manual tie point observation was not carried out. Figure 9 shows tie point distribution of this block.

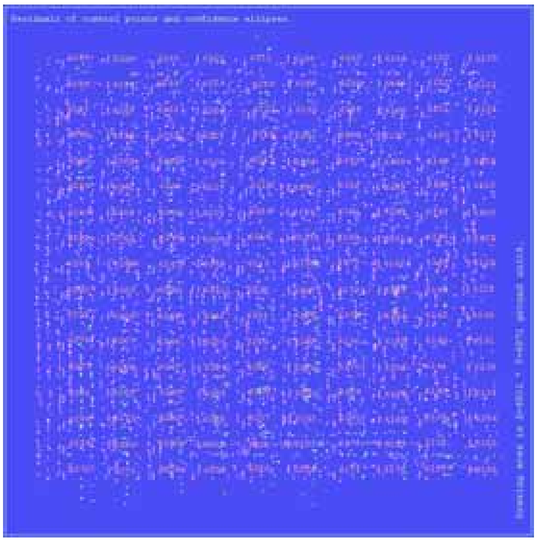

Figure 9. Tie point distribution

3. RESULT AND DISCUSSION

		X	Y	XY	Z	NUM	σ_0
CASE 1 Normal AT 19GCPs	SD	0.104	0.081	0.059	0.128	394pts	9.5μm
	RMS	0.109	0.081	0.135	0.145		
	MAX	-0.264	0.276	0.328	-0.381		
CASE 2 Without GCP	SD	0.063	0.070	0.050	0.067	412pts	9.2μm
	RMS	0.083	0.094	0.125	0.184		
	MAX	-0.241	-0.220	0.246	0.413		
CASE 3 4GCPs Without DS	SD	0.066	0.074	0.051	0.069	408pts	9.2μm
	RMS	0.083	0.097	0.127	0.187		
	MAX	-0.237	-0.219	0.245	0.422		
CASE 4 4GCPs DATUM SHIFT	SD	0.067	0.074	0.046	0.069	408pts	9.2μm
	RMS	0.073	0.082	0.110	0.071		
	MAX	0.203	-0.192	0.244	-0.265		
CASE 5 1GCP Without DS	SD	0.066	0.074	0.052	0.069	411pts	9.2μm
	RMS	0.084	0.096	0.128	0.189		
	MAX	-0.238	-0.218	0.246	0.424		
CASE 6 1GCP DATUM SHIFT	SD	0.066	0.075	0.059	0.069	411pts	9.2μm
	RMS	0.072	0.105	0.127	0.070		
	MAX	0.201	0.272	0.318	-0.260		

Table 10. Result of bundle adjustment

3.1 Result of block adjustment

Bundle block adjustment was performed consequently. Bundle block adjustment software BINGO (GIP) was used for all processing. Only 10 normal strips are used to evaluate block accuracy. The misalignment value was estimated using all strips and all GCPs. The prior standard deviation values were 9μm for image measurement, 10cm for GPS position, 0.014 grad for phi and omega, 0.039 grad for kappa, respectively. Several cases were processed as written below:

CASE1: Normal aerial triangulation（19GCPs, DGS was not used.）
CASE2 : Without GCPs
CASE3 : 4GCPs without datum shift estimation
CASE4 : 4GCPs with datum shift estimation
CASE5 : 1GCP without datum shift estimation
CASE6 : 1GCP with datum shift estimation

The result is shown in Table 10. By introducing exterior orientation parameters produced by DGS makes standard deviation value much smaller than normal AT (CASE 1 was compared with others). Comparisons among CASE 3 and CASE 5, CASE 4 and CASE 6 show that the number of GCP do not effect for achieving the final accuracy. Even if the GCP is not used the result is almost same. CASE 4 and CASE 6 show that the datum shift estimation eliminates systematic error especially for the height and improve final accuracy.

3.2 Result of misalignment estimation

To confirm misalignment estimation accuracy, result of single strip, 2 strips, 3 strips and 4 strips cases are compared with the obtained results of all strips and utilized GCPs. The 4 GCPs lie at the corner of each block and are fixed. This result is shown in Table12.

Even if it is a single strip, misalignment value estimated by adjustment is very close to what was estimated by using all strips and all GCPs. However if datum shifts estimation was introduced at least two or more strips were needed. It seems that more strips improve higher accuracy.

		Without Datum shift estimation			With datum shift estimation		
		P	R	H	P	R	H
ALL Strips&GCPs	Misalignment				0.029	0.028	0.186
	SD				0.001	0.001	0.003
Single Strip	Misalignment	0.031	0.030	0.183	0.033	0.040	0.183
	SD	0.003	0.005	0.009	0.003	0.012	0.009
2 strops	Misalignment	0.032	0.027	0.182	0.032	0.028	0.182
	SD	0.003	0.003	0.007	0.003	0.003	0.007
3 strips	Misalignment	0.030	0.024	0.184	0.030	0.024	0.184
	SD	0.002	0.002	0.006	0.002	0.002	0.006
4strips	Misalignment	0.030	0.027	0.184	0.031	0.027	0.184
	SD	0.002	0.002	0.005	0.002	0.002	0.005

Table 11. Result of the misalignment estimation

		Exterior orientation parameters						Photo point		
		X0	Y0	Z0	φ	ω	κ	X	Y	Z
Normal AT	SD	0.138	0.099	0.107	0.015	0.009	0.004	0.053	0.048	0.132
	MAX	0.348	0.248	0.283	0.041	0.027	0.009	0.164	0.129	0.430
4GCPs	SD	0.051	0.051	0.060	0.004	0.004	0.003	0.052	0.047	0.097
	MAX	0.060	0.060	0.069	0.007	0.007	0.008	0.110	0.093	0.168

Table 12. Internal accuracy of normal AT and simultaneous adjustment

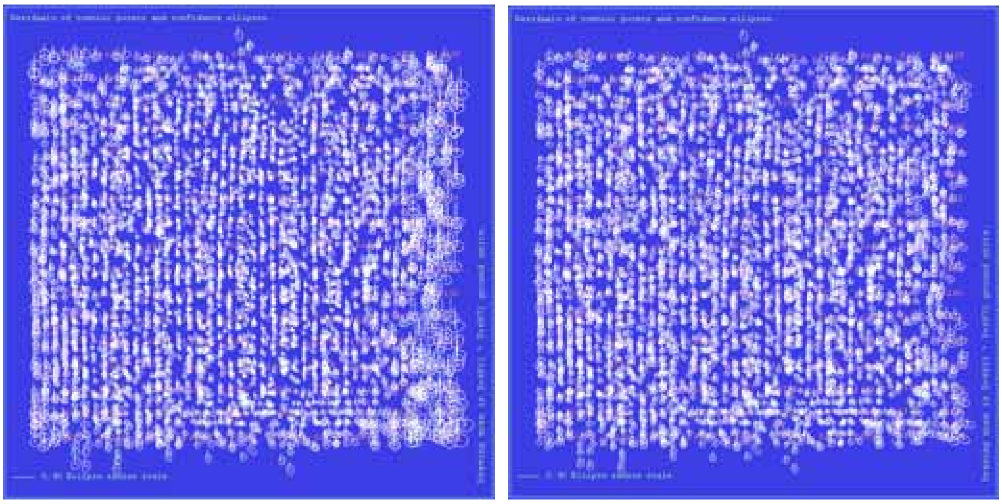

Figure 13. Error ellipsoid of normal AT (left) and simultaneous adjustment (right)

3.3 Result of internal accuracy

Comparison of internal accuracy between normal aerial triangulation and simultaneous bundle adjustment with 4 GCPs is also shown in Table 13. Figure 14 is a plot of the error ellipsoid.
This test block has dense and tie points were well-distributed. Therefore even exterior orientation parameters derived from DGS is not introduced, internal accuracy was higher than manual aerial triangulation. Additionally, simultaneous adjustment improved the block accuracy especially at the periphery of the block.

4. CONCLUSION

It is confirmed that simultaneous bundle adjustment using POS AV/DG 310 has sufficient accuracy level for large scale mapping. Automatic tie point generation using exterior orientation parameters produced by DGS made dense and high accurate tie points and block geometry were noticed more stronger. Datum shift estimation eliminated systematic error. Simultaneous misalignment adjustment is also possible if block has two or more strips.

5. ACKNOWLEDGMENTS

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