GEOMETRIC ACCURACY INVESTIGATION OF VEXCEL ULTRACAMD

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ABSTRACT:

Vexcel announced their first large format aerial camera UltracamD(UCD) at ASPRS Anchorage in May 2003. Three years later UltracamX(UCX) successor model of UCD is announced at ASPRS Reno. In June 2004 PASCO Corporation introduced first UCD and continuously introduced second UCD in December. Since then PASCO has carried out many large scale mapping projects and also orthophoto projects up to now. The average project number is nearly 100 per year and almost 90,000 images are processed. In April 2007 PASCO introduced two UCXs and now it is also used for high resolution digital image acquisition. All of our UCD and UCX are integrated with APPLANIX POS AV310. In some case, for instance small scale orthophoto projects, direct georeferencing without adjustment is performed. The large format aerial frame digital camera VEXCEL UCD, UCX and INTERGRAPH DMC is now getting popular in Japan. At least more than 15 digital frame cameras are operated by several mapping companies. The Japanese mapping standard for public mapping which includes rules about large format aerial digital frame camera was published in April 2008. Currently, various investigations and research projects about geometric accuracy are carried out and systematic error which remained after laboratory calibration is also analysed. In this paper we report systematic error situation about UCD and result of geometric accuracy investigations.

1. INTRODUCTION

Large format aerial frame camera is now standard equipment for mapping project. Since these cameras have unique design to capture large format images, it is very important to check its characteristics and potential. Pasco Corporation has carried out several geometric accuracy investigations of UCD and UCX at Toyonaka field where large number of check points is available and Matsuda field owned by Japan Society of Photogrammetry and Remote Sensing (JSPRS) where check point are well distributed 3 dimensionally. 8-9 cm and 15-16cm of ground sampling distance are selected since these settings are mainly used for scale of 1:500 and 1:1,000 large scale mapping. Specifications of UCD and UCX are shown in Table 1.

	UCD	UCX
Image size (Pan)	11,500*7,500	14,430*9,420
(R,G,B,NIR)	4,008*2,672	4,992*3,328
Pixel size	9.0µm	7.2µm
Focal length	101.4mm	100.5mm
B/H ratio (@60%lap)	1/3.76	1/3.70

Table 1. Specifications of UCD and UCX

In case of our standard mapping projects, exterior orientation parameters derived from APPLANIX POS system, tie points processed by automatic image matching and four GCPs at corner of the image block are used for simultaneous bundle adjustment. In this paper we report about the systematic error and the result of geometric accuracy investigation of UCD and UCX.

2. INVESTIGATION OF SYSTEMATIC ERROR

2.1 Systematic error detected by simultaneous adjustment with self calibration

Datum shift between GPS and reference coordinate system, GPS antenna offset, IMU misalignment and camera interior orientation parameters are detected as systematic error during simultaneous bundle adjustment. The camera calibration report of UCD and UCX is provided after lab calibration and test flight. In this case, radial distortion of each lenses are corrected and final distortion value of stitched image is less than 2 micron meter. The coordinate of principal point is fixed at 2 micron meter level as well. There are no systematic errors remaining on the residual vector map in the calibration report. However radial distortion of 5-3 micron meter level are detected from actual image blocks when the self-calibration parameters are introduced and estimated. From several examples during past 3 years it seems that the estimated radial distortion value of two UCDs are almost constant. However sometimes it becomes two times lager than usual. The flight date and information are given in Table.2. and Table.3 and detected radial distortions are shown in Figure 1 and Figure 2.

*Corresponding author

DATE	SITE	GSD	Exposure	f-stop	Strips	Images
20050921	TAKATSUKI	GSD8cm	500	11	8	208
20060418	CHOFU	GSD8cm	500	8	7	154
20060418	CHOFU	GSD16cm	500	8	4	88
20061108	CHOFU	GSD8cm	350	11	7	154
20061108	CHOFU	GSD16cm	500	11	4	88
20070328	CHOFU	GSD8cm	500	16	7	154
20070328	CHOFU	GSD16cm	500	16	4	88
20071122	CHOFU	GSD8cm	500	11	7	154
20071122	CHOFU	GSD16cm	500	11	4	88

Table 2. Flight information of UCD1

DATE	SITE	GSD	Exposure	f-stop	Strips	Images
20050918	CHOFU	GSD8cm	500	11	7	154
20051116	CHOFU	GSD8cm	500	11	7	154
20061110	TAKATSUKI	GSD8cm	90,120,175	5.6	8	208
20070414	CHOFU	GSD8cm	500	16	7	154
20070414	CHOFU	GSD16cm	500	16	4	88
20070526	CHOFU	GSD8cm	500	16	7	154
20070526	CHOFU	GSD16cm	500	16	4	88
20070612	CHOFU	GSD8cm	500	16	7	154
20070612	CHOFU	GSD16cm	500	16	4	88
20080402	CHOFU	GSD8cm	500	16	7	154
20080402	CHOFU	GSD16cm	500	11	4	88

Table 3. Flight information of UCD2

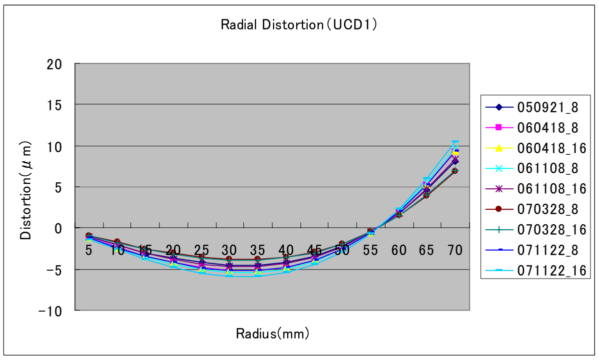

Figure 1. Radial distortion of UCD1

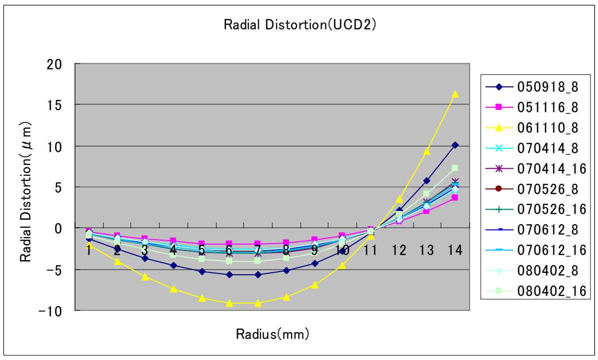

Figure 2. Radial distortion of UCD2

2.2 Simulation of radial distortion

To check the influence of radial distortion on the ground, simulation data was used. This block has 6 strips with 21 images. 5*5 tie point are distributed on each images. Each image coordinates were transferred by adding radial distortion influence (Table 5.).

Strip Num	6
Image Num	126
Tie Point Config	5*5
Lap (Track-Crosstrack)	80-80

Table 4. Specification of simulation block

Radius(m)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
Distortion(μm)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.0	2.5	2.0	1.5	0.5	-1.0	-3.0	-5.0

Table 5. Assigned radial distortion value

From simulation adjustment, it is confirmed that the radial distortion caused about 1.4 pixel influence to the height accuracy. In case of large scale mapping, it is not negligible amount. The result is given in Table6.

	X	Y	XY	Z
RMS(m)	0.01	0.01	0.01	0.13
SD(m)	0.01	0.01	0.01	0.02
AVERAGE(n	0.00	0.00	0.01	-0.13
MAX(m)	0.02	0.03	0.03	-0.06
MIN(m)	-0.02	-0.03	0.00	-0.16

Table 6. Influence of radial distortion

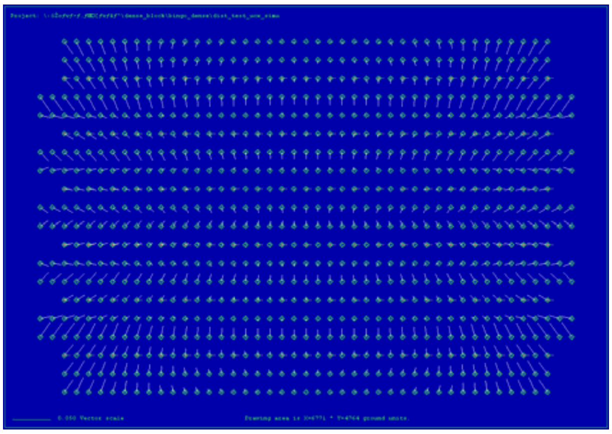

Figure 3. Planimetric influence of radial distortion

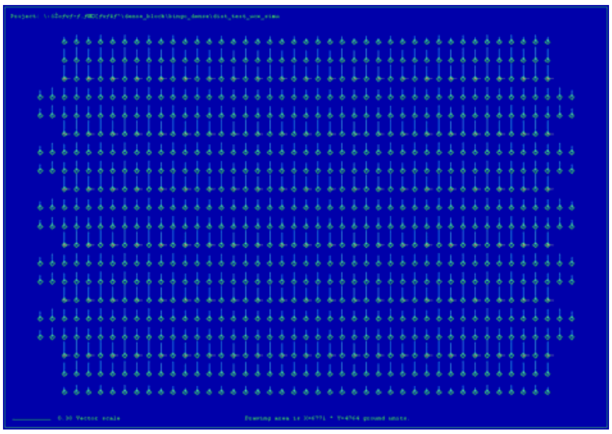

Figure 4. Vertical influence of radial distortion

3. GEOMETRIC ACCURACY INVESTIGATION

To investigate geometric accuracy, 3 projects (1 UCD project and 2 UCX projects) have been carried out at Toyonaka site and Matsuda site.

3.1 Test Site

3.1.1 Toyonaka: Toyonaka field has large number of GCPs. Almost GCPs are laid underground and covered by concrete box (Figure5.). The dimension of cover is about 30cm by 30cm. The distance between GCP point and top of the cover is measured and recorded. The height difference is about 60m. The distribution of GCPs is shown in Figure 6.

Figure 5. GCP at Toyonaka site

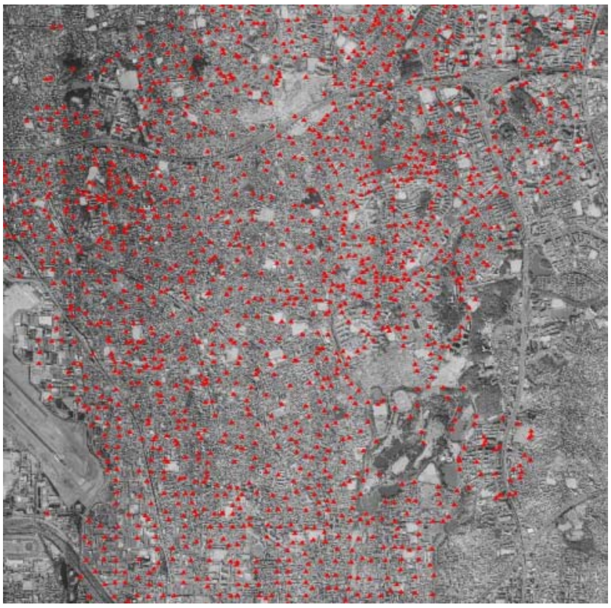

Figure 6. Toyonaka site

3.1.2 Matsuda: Matsuda field is established by JSPRS to investigate geometric accuracy of aerial sensors. 64 points of check points are well distributed 3 dimensionally. The maximum height difference is about 360m. Circle shape target is adopted (Figure 7.).

Figure 7. Circle shape of GCPs

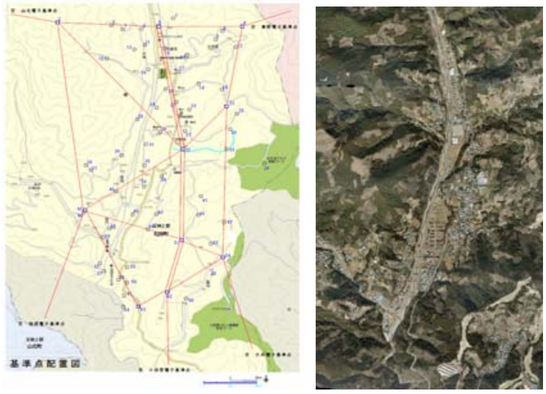

Figure 8. MATSUDA site

3.2 Test Block

3.2.1 UCD_MATSUDA: UCD Matsuda project has done at 9cm GSD and 15cm GSD. 80% - 60% (Track-Cross track) over lapped images were captured and 2 of 60% - 30% lapped blocks were extracted for each GSD.

3.2.2 UCX_TOYONAKA: UCX Toyonaka project has also done at 8cm GSD and 16cm GSD. 80% - 30% (Track-Cross track) over lapped images were captured and 2 of 60% - 30% lapped blocks were extracted.

3.2.3 UCX_MATSUDA: UCX Matsuda project has only 8cm GSD. 80% - 30% (Track-Cross track) over lapped images were captured and 4 of 60% - 30% lapped blocks were extracted.

3.3 Result of Simultaneous adjustment

To check the radial distortion influence, adjustment with and without radial distortion parameter were carried out. In these cases, all images were used. Continuously extracted 60% - 30% lapped blocks were adjusted. 4 corner GCPs were used in all cases. The results of each adjustment are given in Table 7. The plot of planimetric and vertical RMS and SD value are shown in Figure 9.~Figure 13. RMS and SD value is calculated by $\sqrt{\frac{\sum x^2}{n}}$ and $\sqrt{\frac{n\sum x^2 - \sum x^2}{n}}$ where x is residuals and n is point number.

	GSD	RMS_XY(m)	RMS_Z(m)	SD_XY(m)	SD_Z(m)	σ 0(μ m)	Strips	Images	GCPs	CHCK s	LAP
UCD MATSUDA											
GSD 9cm all	9cm	0.040	0.104	0.022	0.077	3.1	12	360	4	56	80-60
GSD 9cm all woRD	9cm	0.047	0.129	0.021	0.085	3.1	12	360	4	56	80-60
GSD 9cm 1	9cm	0.058	0.129	0.034	0.111	2.9	4	60	4	54	60-30
GSD 9cm 2	9cm	0.071	0.113	0.038	0.108	3.2	4	60	4	49	60-30
GSD 15cm all	15cm	0.068	0.086	0.049	0.066	2.1	7	207	4	50	80-60
GSD 15cm all woRD	15cm	0.124	0.103	0.058	0.102	2.1	7	207	4	50	80-60
GSD 15cm 1	15cm	0.103	0.195	0.056	0.186	1.7	3	33	4	48	60-30
GSD 15cm 2	15cm	0.093	0.170	0.044	0.157	1.6	3	30	4	48	60-30
UCX TOYONAKA											
GSD 8cm all	8cm	0.109	0.113	0.051	0.112	1.6	3	117	4	121	80-30
GSD 8cm all woRD	8cm	0.113	0.120	0.054	0.120	1.6	3	117	4	121	80-30
GSD 8cm 1	8cm	0.100	0.139	0.045	0.139	1.8	3	59	4	120	60-30
GSD 8cm 2	8cm	0.124	0.134	0.061	0.130	1.8	3	58	4	117	60-30
GSD_16cm_all	16cm	0.106	0.146	0.060	0.144	2.3	5	100	4	101	80-30
GSD 16cm all woRD	16cm	0.130	0.152	0.066	0.149	2.2	5	100	4	101	80-30
GSD 16cm 1	16cm	0.105	0.143	0.055	0.141	2.1	3	30	4	81	60-30
GSD 16cm 2	16cm	0.098	0.166	0.048	0.151	2.1	3	30	4	68	60-30
UCX MATSUDA											
GSD 8cm EVEN all	8cm	0.047	0.083	0.020	0.074	1.5	4	64	4	55	80-30
GSD 8cm ODD all	8cm	0.045	0.064	0.022	0.063	1.5	4	64	4	57	80-30
GSD 8cm EVEN all woRI	8cm	0.088	0.123	0.037	0.098	1.5	4	64	4	55	80-30
GSD 8cm ODD all woRD	8cm	0.066	0.082	0.028	0.082	1.5	4	64	4	57	80-30
GSD_8cm_EVEN_EVEN	8cm	0.044	0.112	0.020	0.090	1.7	4	32	4	53	60-30
GSD 8cm EVEN ODD	8cm	0.045	0.085	0.020	0.080	1.7	4	32	4	55	60-30
GSD 8cm ODD EVEN	8cm	0.061	0.103	0.029	0.095	1.6	4	32	4	56	60-30
GSD 8cm ODD ODD	8cm	0.054	0.084	0.026	0.083	1.7	4	32	4	57	60-30

Table 7. Result of each adjustment

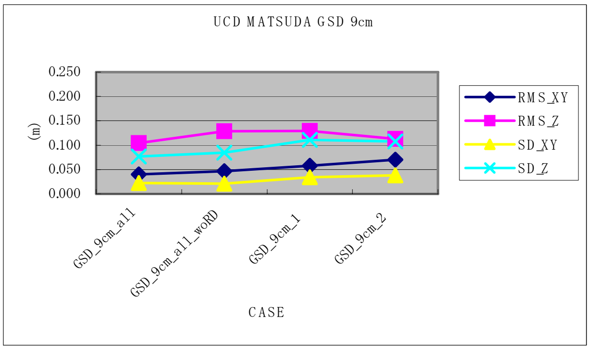

Figure 9. UCD MATSUDA GSD 9cm

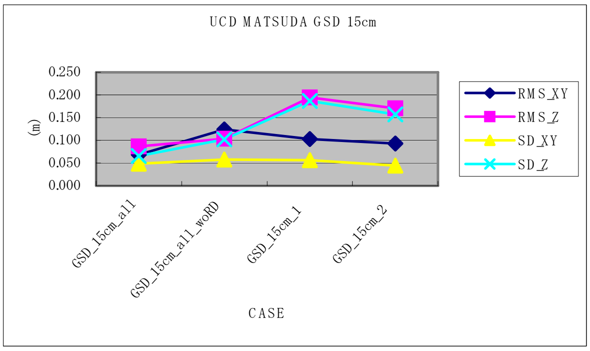

Figure 10. UCD MATSUDA GSD 15cm

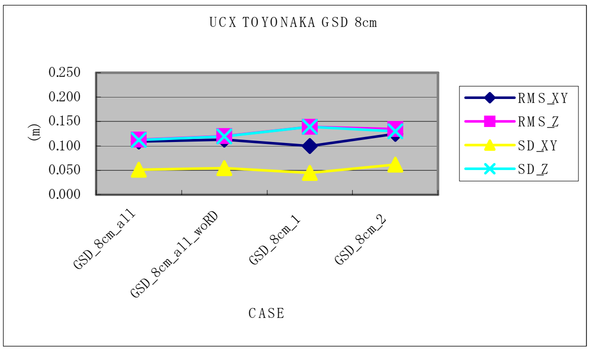

Figure 11. UCX TOYONAKA GSD 8cm

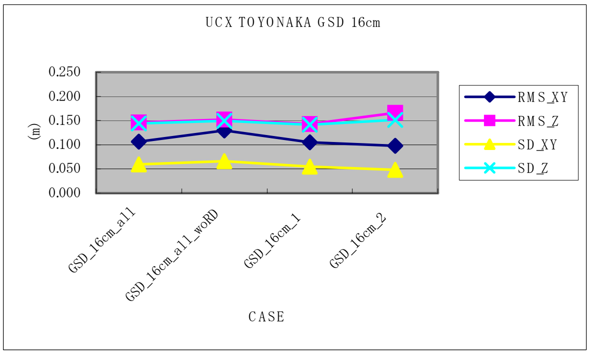

Figure 12. UCX TOYONAKA GSD 16cm

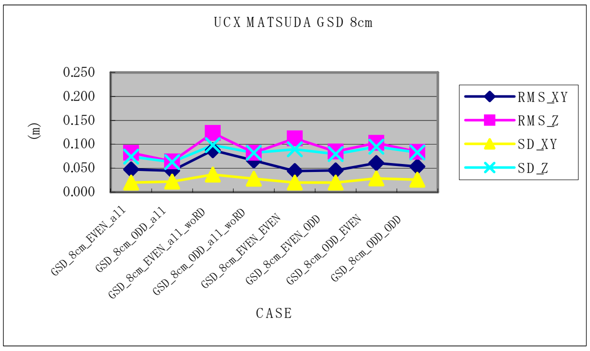

Figure 13. UCX MATSUDA GSD 8cm

3.4 Discussion

The σ_0 value of simultaneous bundle adjustments are 1/3 to 1/5 pixel and it is always stable. In case of 8-9 cm GSD block, the RMS value of planimetric check points is corresponding to 1 to half pixel and RMS of elevation is about 1 to 1.4 pixels. In case of 15-16 cm GSD block, RMS value of planimetric check points is 2/3 pixel and RMS of elevation is around 1 to 1.5 pixels. In both cases RMS of horizontal position is about 2 times lager than its standard deviation value while RMS value of elevation are very close to the standard deviation value. It seems that almost vertical systematic error has been eliminated by simultaneous adjustment. The B/H ratio of UCD and UCX at 60% lap is about 1/3.7 while the ratio between horizontal and vertical RMS value is 1/1 to 1/2.5. It is always better than theoretical accuracy calculated by base-height ratio.

4. CONCLUSION

It is confirmed that UCD and UCX has very high geometric accuracy. It is also confirmed that the systematic error especially radial distortion is still remaining in the actual image block. Camera calibration is carried out in laboratory and there are big difference between lab and actual photo mission environment. Atmospheric reflection also has some influence. It seems that these difference is one of the reason of systematic error. Comparing to the standard aerial camera, image scale of UCD and UCX is much smaller. Even systematic error is small on the image it may cause large error on the ground. Radial distortion correction is supported by all of digital photogrammetric work station and this correction is effective for quality control. The reason of unusual lager distortion issue is still under consideration.

Currently self-calibration parameters based on the sensor model of UCD and UCX are not supported by DPWs. Vexcel recommends on-site calibration and update calibration file. It is very important to take into account of the change of camera parameters if highest accuracy is needed. Applying standard distortion parameters did show that excellent results were achievable. A vertical accuracy up to 0.5 GSD RMS could be observed (this is about 0.04 o/oo of the flying height). Even better result can be achieved when camera specific parameters are introduced into the adjustment and thus a full auto calibration is performed.

REFERENCES FROM JOURNALS

M. Gruber, R.Ladstädter, 2008 CALIBRATING THE DIGITAL LARGE FORMAT

AERIAL CAMERA ULTRACAM*X*, International Calibration and Orientation Workshop EuroCOW 2008

KARSTEN JACOBSEN, 2008.OMETRIC CHARACTERISTICS OF LARGE SIZE AERIAL FRAME CAMERAS, International Calibration and Orientation Workshop EuroCOW 2008

Gruber, M., 2007: UltraCamX, the new Digital Aerial Camera System by Microsoft Photogrammetry, Proceedings of the Photogrammetric Week 2007, Stuttgart 2007