TESTING A DIGITAL LARGE FORMAT CAMERA

B. Arias [a], D.A. Nafría [b], V. Blanco [b], O.O. Rodríguez [b], M. Blanco [b], F.J. Antolín [b], J. Rodríguez [c], J. Gomez [c]

[a] Dept. of Cartographic, Geodesic Engineering and Photogrammetry, Leon University, Astorga Avenue, Ponferrada, Spain – benjamin.arias@unileon.es
[b] Agricultural Technological Institute of Castilla y León (ITACYL), Ctra. Burgos-Portugal km 119, 47071, Valladolid Spain – nafgarda@itacyl.es,
[c] School of Geodesy and Cartography Engineering , Salamanca University, Hornos Caleros 50 Street, Avila, Spain – fotod@usal.es

KEY WORDS: Accuracy, Camera, Comparison, Pixel, Precision, Quality, Statistics, Stereoscopic.

ABSTRACT:

Digital large format cameras render a final image that is the composition of diverse medium format images with different lenses. This final output is achieved for a predefined principal length and principal point position and it's assumed to be from distortions to certain accuracy. To check these statements two flights with different flying heights with GSDs of 0.075 m and 0.150 m. have been projected over the calibration test field built in Valladolid by the Agricultural Technological Institute of Castilla y León (ITACYL, Spain). Due to fact that there are no relieves at the zone, the two different flying heights become necessary to compute the inner camera parameters. Besides this, we have carried out an analysis of the impact that the selection of different additional parameters have on the residuals of the bundle adjustment computation. The software we have used in the automatic measurements of tie points is Match-AT v5 from Inpho while the computation of the Aerotriangulation with additional parameters has been done with Bingo v.5.4.

1. INTRODUCTION

The large format digital cameras images are obtained by processing several single sub images, each of them attached to physical CCDs. To attain this target, the camera and its different elements are carefully calibrated in a laboratory. Nevertheless, the flying conditions are not the same as the laboratory conditions and so, some residual errors in the image observations arise.

In the Congress of the EuroCOW celebrated in 2006, Barcelona, some of the papers deal with this issue while trying to harness the use of additional parameters to render the behaviour of the images from the Vexcel UltraCamD and Z/I DMC. While some authors propose to apply the so called Ebner parameters for the DMC, either for the whole image (Honkavaara et al, 2006a) or either for the different zones of this same camera (Kornus, 2006), some other authors use specific sets of additional parameters for the DMC and for the UltracamD (Gruber et al, 2006; Kruck, 2006). Some other contributions, after this Congress, continue the same line (Honkavaara et al, 2006b, 2006c; Alamús, 2006).

In the Congress of Hannover, in 2007 some more papers regarding the use of additional parameters for the UltraCamD and the DMC are presented (Alamús et al, 2007; Baz et al, 2007; Jacobsen, 2007; Spreckel et al, 2007).

In the Photogrammetric Week of the year 2007, a contribution is presented that applies the additional parameters on the new camera UltraCamX (Gruber, 2007) while some new strategies for the DMC appear, such as the consideration of a correction grid in the generation of the virtual image or the use of four grids derived by a collocation technique (Dörstel, 2007).

2. MATERIALS AND METHODS

2.1 Flights

A flight with two different heights has been performed with GSDs of 0,075 m and 0,150 m. Provided that one of our goals is to asses both the principal distance and the position of the principal point and due to the fact that the relieves of the zone are small it becomes a must to acquire and to process images from different flying heights.

A total amount of 11 control points, were presignalized and observed. The shape of the strips is depicted in figure 1 and the diverse arrangements used in the computations are collected in table 1.

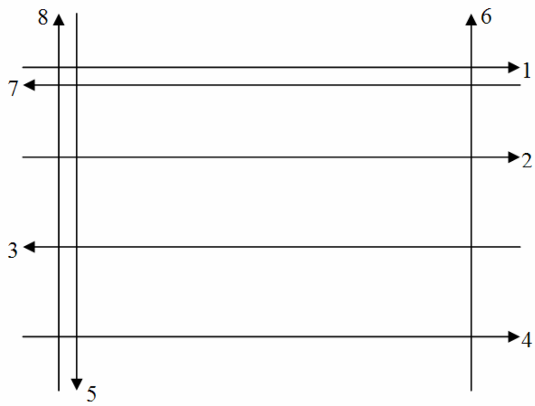

Figure 1. Configuration of strips flown at two flying heights. Strips 1 and 7 and strips 5 and 8 are double, strips with the same trajectory but with opposite directions.

Configuration	*Strips*
A	All
B	7, 2, 3, 4
C	1,7
D	1, 5, 7, 8
E	7, 2, 3, 4, 5, 6

Table 1. Different flying configurations. A: all the strips; B: only East West strips; C: T Shape; D: Cross shape; E: 4 East - West strips and two North - South strips. All the strips are composed by 24 images.

This strip configuration is due to the fact that besides the principal distance, other elements concerning the GPS/INS system are also analyzed.

2.2 Measures

Measures, both manual and automatic, were performed with Match-AT, v.5. To guarantee a reliable computation of the bundle adjustment of both flights, about 100 tie points were manually measured on each of them.

2.3 Computation

The computation of the Aerotriangulation has been done with Bingo v.5.4. This software computes both the principal distance and the position of the principal point and includes the computation of additional parameters. The most relevant features of these items are presented in the following.

2.3.1 Principal distance and position of the principal point: there are four possibilities: both to be fixed as constants; principal distance unknown and position of the principal point constant; principal distance fixed and position of the principal point unknown; and finally, both computed as unknowns.

2.3.2 Additional parameters: Bingo applies the Mueller, Bauer and Jacobsen 24 parameters function. In addition, it uses a series of special additional parameters for the large format digital cameras UltraCamD from Vexcel (UCD) and DMC from Z/I (DMC). Bingo takes into account the modular composition of the unique final image and consequently, performs the calculation of additional parameters related to nine zones for the UCD and 4 zones for the DMC (see figure 2).

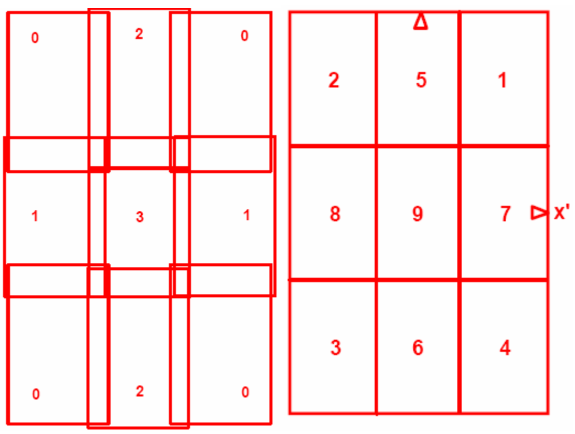

Figure 2. Left: arrangement of the 9 CCDs of the UltraCamD from Vexcel, grouped on the 4 cones (0 to 3), where cone #0 corresponds to the master cone. Right: numbers of CCD according to BINGO. (Original figures from the BINGO user guide).

The user guide suggests to apply different combinations of parameters 17, 31, 32 and 34 for all the CCDs except for the central one (CCD number 9) to which only parameter 9 must be applied.

- 17: shear
- 31, 32: Shifts in x' resp. in y'
- 34: Scale

By default, Bingo executes some statistical tests to filter the additional parameters:

- Correlation test: If two additional parameters correlate with each other by a coefficient larger than 0.80 these parameters are not independent. Therefore one can be omitted.
- Significance test: If the value of an additional parameter is below a given noise level, this parameter should be omitted.
- Total correlation: The total correlation indicates to what extent a parameter can be replaced by the other parameters and therefore is redundant.

The automatic suppression of additional parameters may not be applied, because it implies the elimination of parameters attached to different CCDs (see figure 2). Our approach is explained in the following topic.

3. RESULTS AND DISCUSSION

3.1 Additional parameters

We observe that automatic elimination of additional parameters is applied within the parameters attached to different CCDs that integrate the UltraCamD. For example, parameter 317 (parameter 17 of CCD 3) may show a high correlation with parameter 534 (parameter 34 of CCD 5) and thus, is cancelled. We reckon that, as long as parameters could describe the behaviour of different CCDs, they should not be compared with the corresponding parameters of other cones and only should be compared - and, if it is the case, eliminated - with the parameters of the same cone.

Consequently, we accomplish the assessment of the additional parameters through the quotient between the parameter value and its standard deviation. If this figure is above ten the parameter is considered relevant, and eliminated if it is not.

3.1.1. Within CCD: We present and analyze here the correlation between parameters that belong to the same CCD.

CCD	*par*	*val*	S_p	val/S_p
1	17	0.3	0.1	5.3
1	31	-0.3	0.0	-10.9
1	32	-0.7	0.0	-18.5
1	34	-1.8	0.1	-17.9
2	17	-0.4	0.1	-8.6
2	31	0.6	0.0	24.0
2	32	-1.3	0.0	-38.0
2	34	2.2	0.1	23.1
3	17	-0.1	0.1	-2.3
3	31	0.8	0.0	28.7
3	32	1.6	0.0	39.8
3	34	0.7	0.1	7.0
4	17	2.1	0.1	30.0
4	31	0.0	0.0	0.1
4	32	2.9	0.0	66.8
4	34	0.5	0.1	4.2
5	17	-1.1	0.1	-19.9
5	31	0.0	0.0	-3.3
5	32	0.5	0.0	13.3
5	34	-2.5	0.1	-27.0
6	17	-2.0	0.1	-30.6
6	31	0.1	0.0	7.0
6	32	-1.4	0.0	-34.9
6	34	-4.4	0.1	-44.5
7	17	-1.5	0.1	-29.9
7	31	0.3	0.0	12.6
7	32	0.5	0.0	44.0
7	34	-5.2	0.1	-71.4
8	17	-1.8	0.0	-39.2
8	31	-0.2	0.0	-8.9
8	32	0.2	0.0	19.7
8	34	-2.8	0.1	-41.9
9	17	-0.8	0.0	-17.8

Table 2. Initial results from the flight configuration E, with GSD of 0.075 m., grouped by CCDs, where *par*: parameter; *val*: value of parameter; S_p: standard deviation of value; val/S_p: quotient between the value of parameter and its standard deviation.

From the parameters collected in table 2, we eliminate all that show a quotient between the value and the correspondent standard deviation larger than 10. In the following table, we show the correlation between parameters, clustered by CCDs.

CCD	*par*	*correl.*
1	31-32	1
1	31-34	-42
1	32-34	-61
2	31-32	4
2	31-34	35
2	32-34	-59
3	31-32	-2
4	17-32	70
5	17-32	-66
6	17-32	72
6	17-34	24
6	32-34	63
7	17-31	74
7	17-32	1
7	17-34	-35
7	31-32	4
7	31-34	-59
7	32-34	-8
8	17-32	1
8	17-34	-38
8	32-34	-8
9	17	---

Table 3. Correlations between parameters, clustered by CCDs.

We can appreciate that there is no correlation above 80% and so all the parameters are considered to be meaningfull, so, none is eliminated. In this way we obtain the results of table 4.

CCD	*parameters*
1	31,32,34
2	31,32,34
3	31,32
4	17,32
5	17,32
6	17,32,34
7	17,31,32,34
8	17,32,34
9	17

Table 4. Parameters to be used, according to a CCD clustering.

3.2 Principal distance and position of the principal point

The principal distance and the position of the principal point have been assessed through the E configuration of table 1, with the information derived of the two flying heights and more than 100 manual measured tie points besides the tie points measured by matching in both flights. The results are collected in the table below.

Unknown	*c*	*xH, yH*	*c, xH,y H*
c	101.4067	101.4000	101.3998
xH	0.0000	-0.0033	-0.0033
yH	0.0000	0.0175	0.0175
S_c	0.0007	---	0.0007
S_{xH}	---	0.0002	0.0002
S_{yH}	---	0.0003	0.0003
σ_0	0.73	0.72	0.71

Table 5. Results of the computation of the principal distance and the position of the principal point for the E configuration, where c: principal distance; xH, yH: coordinates of the principal point; S_c, S_{xH}, S_{yH}: standard deviations; σ_0; sigma naught of the bundle adjustment.

The value of σ_0 enforcing *c, xH,y H* to be constant was of 0,73.

4. CONCLUSIONS

Due to paper restrictions, only the results of one flight configuration have been presented above. Nevertheless, the following conclusions are derived from the whole set of configurations.

We find that parameter 31 shows, both in its values an in its standard deviation, no systematic tendency at all. On the contrary, parameter 32 shows a well defined trend: it throws, not only the lowest deviations, but also a high regularity within all the configurations. If we except CCD 5, in which erratic figures are obtained, the rest of CCDs can be grouped, through the different configurations, into close values. In addition, this behaviour confirms the results of table 5 in which we can see a peculiar value for the Y component of the principal point whereas no comment at all can be done for the correspondent value of the X component.

The results of parameters 17 and 34 can be considered half the way between consistency and non consistency. Specially meaningful among this uncertainty is the behaviour of CCDs 7 and 8 (cone 1) for the results obtained are highly close to each other through all the configurations, both in values and deviations. This suggests that this cone obeys to a systematic factor that does not affect the other ones.

Something rather similar happens with CCDs 5 and 6 (cone 2) but only for those configurations with only east - west strips and not for those configurations with both east - west and north - south strips. In this way, we may conclude that this type of configurations, with crossed strips, "is able" to detect and correct a systematic behaviour of cone 2 while a conventional configuration does not "seem able" to do so.

5. REFERENCES

Alamús, R., Kornus, W., Riesinger, 2007. I. DMC geometric performance analysis. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Hannover, Germany, Vol. XXXVI-1/W51 (on CD-ROM).

Alamús, R., Kornus, W., Talaya, J., 2006. Studies on DMC geometry. In: *ISPRS Journal of Photogrammetry & Remote Sensing*, Vol. 60, pp. 375-386.

Baz, I., Buyuksalih, G., Jacobsen, K., 2007. Bundle block adjustment with high resolution UltraCamD images. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Hannover, Germany, Vol. XXXVI-1/W51 (on CD-ROM).

Dörstel, C., 2007. DMC – (R)evolution on geometric accuracy. In: *The Photogrammetric Week 2007*, Stuttgart, Germany, pp.81-88.

Gruber, M., Ladstädter, R., 2006. Geometric issues of the digital large format aerial camera UltraCamD. EuroCOW 2006.

Gruber, M., 2007- UltraCamX, the New Digital Camera by Microsoft Photogrammetry. In: *The Photogrammetric Week 2007*, Stuttgart, Germany, pp. 137-145.

Honkavaara, E., Jaakkola, J., Markelin, L., Peltoniemi, J., Ahokas, E., Becker, S., 2006a. Complete photogrammetric system calibration and evaluation in the Sjökulla test field – case study with DMC. In: Proceedings of the International Calibration and Orientation Workshop EuroCOW, 25-27 January 2006, Castelldefels, Spain (on CD-ROM).

Honkavaara, E., Ahokas, E., Hyyppä, J., Jaakkola, J., Kaartinen, H., Kuittinen, R., Markelin, L., Nurminen, K., 2006b. Geometric test field calibration of digital photogrammetric sensors. In: *ISPRS Journal of Photogrammetry & Remote Sensing*, Vol. 60, pp. 387–399.

Honkavaara, E., Jaakkola, J., Markelin, L., Nurminen, K., Ahogas, E., 2006c. Theoretical and empirical evaluation of geometric performance of multi-head large format photogrammetric sensors. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Paris, France, Vol. XXXVI-1, Part A (on CD-ROM).

Jacobsen, K., 2007. Geometry and information contents of large size digital frame cameras. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Hannover, Germany, Vol. XXXVI-1/W51 (on CD-ROM).

Kornus, W., Alamús, R., Talaya, J., 2006. Tests and performance analysis of the DMC at the cartographic Institute of Catalonia (ICC). In: Proceedings of the International Calibration and Orientation Workshop EuroCOW, 25-27 January 2006, Castelldefels, Spain (on CD-ROM).

Kruck, E., 2007. User's Manual BINGO v.5.3.

Kruck, E., 2006. Simultaneous Calibration of Digital Aerial Survey Cameras. In: Proceedings of the International Calibration and Orientation Workshop EuroCOW, 25-27 January 2006, Castelldefels, Spain (on CD-ROM).

Spreckels, V., Schlienkamp, A., Jacobsen, K., 2007. Model deformation. accuracy of digital frame cameras. In: *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Hannover, Germany, Vol. XXXVI-1/W51 (on CD-ROM).