

DIGITAL CAMERAS FOR A PHOTOGRAMMETRIC PRODUCTION ENVIRONMENT: A TEST OF THE GEOMETRIC STABILITY AND ACCURACY

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ABSTRACT:

The use of digital cameras in the photogrammetric work flow has gained widespread acceptance over the past few years. Whereas the geometric specifications of analogue aerial cameras have been thoroughly studied over the years and are very well known, the same can not be said about the emerging digital ones. From a large scale aerial mapping point of view, the digital cameras have barely left the crib. Indeed, as with all new technologies not all advantages, nor disadvantages for that matter have already been discovered, nor remediated. This paper presents a test that was set up to evaluate the geometric performances of digital cameras. The test is devised to use close range photogrammetric calibration techniques to check whether the camera can comply with the stringent geometric specifications required for large scale photogrammetric work (as for work within a mapping agency). The entire test procedure consists of several distinct phases and is presented with the results of a flight performed with an Intergraph DMC camera.

1. INTRODUCTION

The use of digital cameras in the photogrammetric work flow has gained widespread acceptance over the past few years. Indeed, these cameras have many advantages over analogue cameras. But the geometric specifications of analogue aerial camera have been thoroughly studied over the years and are very well known. Having been well calibrated these cameras can be used without an afterthought in large scale mapping projects.

Early adopters of digital cameras in the industry have been quite vocal about nearly all aspects on which digital image gathering positively affects the photogrammetric process. But from a large scale aerial mapping point of view these cameras have barely left the crib. Indeed, as with all new technologies not all advantages, nor disadvantages for that matter have already been discovered, nor remediated.

The geometric stability and accuracy of digital aerial cameras for large scale mapping projects has just recently become an issue of concern.

The first generation of digital camera's and factory calibration models suggest systematic distortions, especially in Z when significant height difference occur within an image block (Alamús et al. 2006, Dörstel 2003). Honkvaara et al. (2006) concluded from their research into the geometric accuracy of the UltraCamD that the camera seems suited to replace analog photogrammetric cameras given that the geometric accuracy requirements are not higher than 5µm horizontal in the image space and better than 0,15% of the object distance.

With the advent of the second generation of digital cameras (as the UltraCam-X) a lot of attention has been given to the internal geometric accuracy of the camera. Although current models deliver imagery with planimetric accuracy comparable to analogue cameras, it has been mentioned that the internal geometric accuracy of the camera (especially in Z) should be improved when the imagery is aimed for very large scale

mapping projects. Systematic effects in the block have been reported in projects with several hundred images (Schroth, 2007). The addition of specific calibration parameters substantially improves the accuracy (from 5-10 cm to 3-6 cm), but requires a calibration before use.

Research towards improved techniques for camera calibration are a continuous process whereby residuals in the internal geometry of different cameras are described as best as possible to reduce these residuals to a minimum. Several scientific institutions and/or private companies have started, or are in the midst of research projects aiming at certifying the quality and insuring the quality consistency of digital camera products.

In order to evaluate the performance of these cameras for in-house production processes, an experiment was set up to test their geometric performances. The test is devised to use close range photogrammetric calibration techniques to check whether the camera can comply with the stringent geometric specifications required for large scale photogrammetric work (as for work within a mapping agency).

The entire test procedure consists of several distinct phases. At the moment only frame cameras have been considered since they better match the standard aerial photogrammetric camera configuration than line scanners do. As such, a test flight was carried out with an Intergraph DMC camera and a Vexcel UltraCam-X camera. Only the DMC results will be presented here, as the UltraCam-X results are being processed at the time of writing.

2. METHOD

2.1 Test Field and Flight Plan

For the test flight a large test field was laid out with fixed targets in a semi-regular pattern. This field was pictured from eight different viewing positions and eight different viewing

angles. Four sets of views were taken at a vertical angle and in two flight directions perpendicular to each other. Thus one set of views was taken on the outward journey and another set of views was taken on the backward journey of each flight direction. Four more views were taken at an oblique angle (approximating 35°).

The test field consisted of a central zone and a periferal one. The central zone is a nature reserve and thus unaccessible to the public. The fixed targets were laid out in this central zone. Their X,Y and Z coordinates were recorded shortly before the flight date using a differential GPS. In the periferal zone fewer fixed targets have been used due to the occurrence of several roads and bridges, where road marks were used. The bridges provided points situated well above the terrain level so as to enhance the check on Z residuals.

Het testfield was flown according to following protocol (Figure 1):

1. Two flight axes at right angle are flown in both directions in such a way to obtain overlapping imagery centered on the middle of the test field. These axes are numbered from 1 to 4 on Figure 1. Note that axes 1 and 3 are flown in opposite directions, so are axes 2 and 4.
2. Four oblique images were acquired from four different flight axes (5, 6, 7 and 8 on Figure 1). These flight axes are located at the borders of the project area and are situated at an angle of 45° when compared to axes 1, 2, 3 and 4. The images are taken in such a way that the centre of the test field coincides with the centre of the image. The oblique angle should approach as best as feasible an angle of 45° Axes 5 and 7 are flown in the same direction, as are axes 6 and 8.

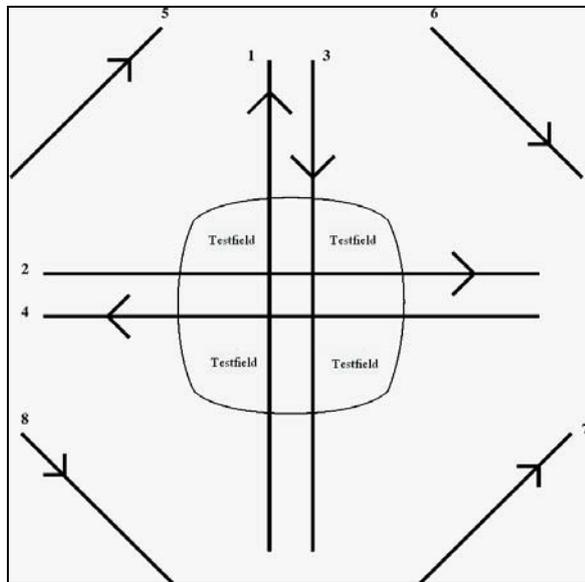


Figure 1. Schematic representation of the flight axes above the test field. Arrows represent the flight direction. Axes 1 and 3 fall together, but have been represented seperately to stress the fact that they are flown from opposite directions. The same is true for axes 2 and 4.

The test flight was carried out in early 2006. The pixel size of the obtained imagery was 7,2 cm, and the imagery was delivered in 16-bit. For this test, only the panchromatic imagery has been used.

2.2 Test Set-Up

The following four steps were taken to evaluate the intrinsic quality of the imagery:

- The acquired imagery is used to form a solid block. This block uses the identified field targets to provide a strong match between all the images.
- A free network least square adjustment with statistical quality analysis is used to verify the correctness of the mathematical model.
- This mathematical model is based on the central projection parametrization whilst using the calibration parameters as provided in the calibration report.
- After it has been proven that the image coordinates are not riddled with mistakes due to observation, a bundle block adjustment with an 'on the job' camera calibration is carried out.

3. RESULTS AND DISCUSSION

Within the large scale mapping projects carried out at AGIV two statistical tests are used to test for the accuracy and quality of the bundle block adjustment. The first one is a Fisher test, the second is a W-test.

The bundle block adjustment is statistically accepted when the Fisher test < 1.1 and 98% of all the observations have a W-test < 3,29 and 100% of the observations < 4. Table 1 gives an overview of the statistical test results :

		Parameters
Fisher-test		0.96
W-values	< 1	64.4%
	<2	93.2%
	<3	98.3%
	<4	99.8%

Table 1. Results of the statistical tests

Overall the bundle block adjustment passes the quality and accuracy requirements for large scale mapping projects. Although a very small percentage (0,02%) of observations have a W-test value greater than 4, we can conclude that these are insignifiant.

The residues on the passpoints are represented in a plot in Figure 2 and Figure 3. From the planar residue plot it is clear that the vast majority of planar residues are smaller than half a pixel (3,6cm), and most fall within the quarter pixel (1,8cm) range.

The plot also confirms the absence of any spatial pattern.

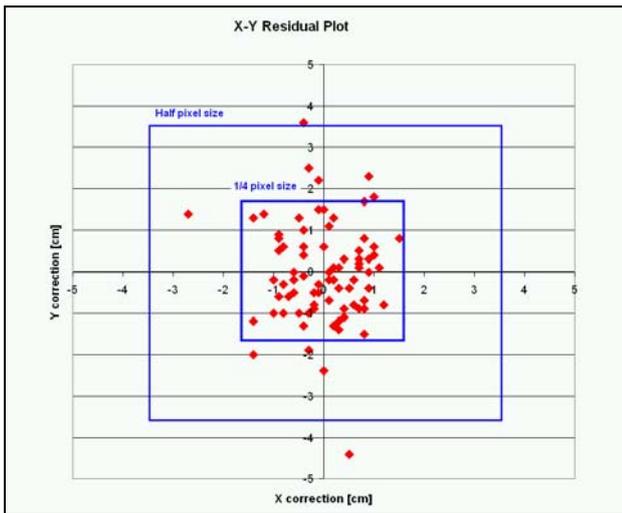


Figure 2. Planar residues on passpoints

The vertical residue plot (Figure 3) shows a similar pattern, although much more residues situate themselves within the quarter to half pixel size. Again, there is no recognizable spatial pattern.

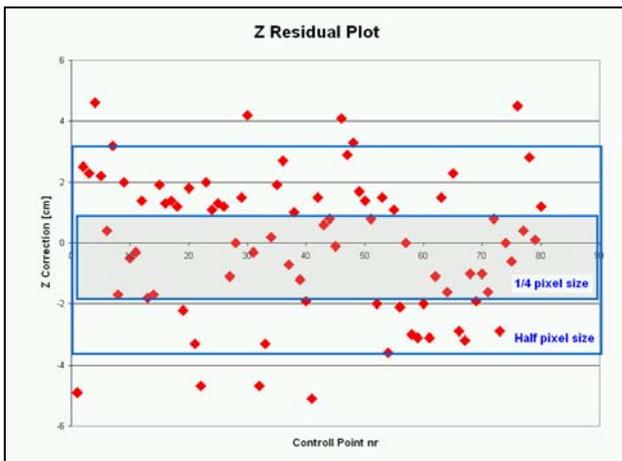


Figure 3. Vertical residues on passpoints

When observing the standard deviation of the residues, a more differentiated interpretation of the results is possible.

	Standard Deviation [cm]
X	0,7560
Y	1,1981
Z	2,2972

Table 2. Standard deviation of residues

The standard deviation in Z is significantly higher than for X and Y. This being said, the standard deviation falls well within the limits of acceptable variations (less than half a pixel).

4. CONCLUSIONS

Based on this test we conclude that the internal geometric properties of the Intergraph DMC camera are enough (sub pixel level) to guarantee accurate quality levels for large scale mapping projects.

These results can not be generalised towards other digital cameras, the internal image build-up differs too much. The specified interior orientation parameters have thus to be tested for each different system.

Distortions found on some some control points are not representative and can be attenuated with the use of additional parameters.

Further research will apply the presented method to other frame digital cameras.

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