



## INFLUENCE OF DIGITAL CAMERA ERRORS ON THE PHOTOGRAMMETRIC IMAGE PROCESSING

Jūratė Sužiedelytė-Visockienė, Domantas Bručas

*Department of Geodesy and Cadastre,  
Vilnius Gediminas Technical University,  
Saulėtekio al. 11, LT-10223 Vilnius, Lithuania  
E-mail: gkk@ap.vgtu.lt*

*Received 2008 10 12, accepted 2008 12 23*

**Abstract.** The paper deals with the calibration of digital camera *Canon EOS 350D*, often used for the photogrammetric 3D digitalisation and measurements of industrial and construction site objects. During the calibration data on the optical and electronic parameters, influencing the distortion of images, such as correction of the principal point, focal length of the objective, radial symmetrical and non-symmetrical distortions were obtained. The calibration was performed by means of the *Tcc* software implementing the polynomial of Chebichev and using a special test-field with the marks, coordinates of which are precisely known. The main task of the research – to determine how parameters of the camera calibration influence the processing of images, i.e. the creation of geometric model, the results of triangulation calculations and stereo-digitalisation. Two photogrammetric projects were created for this task. In first project the non-corrected and in the second the corrected ones, considering the optical errors of the camera obtained during the calibration, images were used. The results of analysis of the images processing is shown in the images and tables. The conclusions are given.

**Keywords:** photogrammetric measurements, calibration of photo cameras, error of camera optics, photo-triangulation, stereo-digitalization, 3D model.

### 1. Introduction

Recently the methods of digital photogrammetry based on the images processing by the special softwares together with a 3D laser scanning are being implemented for the 3D digitalisation of the industrial, architectural heritage, construction site etc objects.

The images for photogrammetric purpose are taken by the analogue or digital photo cameras. To control the precision of optical system and compensate the optical distortions, photo cameras usually are calibrated before the use. There are 3 different methods of optical errors calculation (correction of principal points, focal length, and lens distortion characteristics).

- Before surveying. In a laboratory the unknown elements of internal orientation and distortion of lens shall be defined. The advantage of this method is that the calibration takes place under laboratory conditions and hence better accuracy at defining of unknown quantities is achieved. The problem is that none of the laboratories are available in Lithuania.
- Calibration during the image processing. The unknown parameters are defined by means of mathematical polynomial. During the images process-

ing a large number of geodetic control points is needed – it is recommended to have at least 5 points per geometric model.

- Self-calibration. The images of a test-field with approximately known coordinates are taken from different positions and directions. All unknown parameters (errors of optical system) are mathematically calculated by the overlapping areas on the images.

Determining the parameters of photo cameras (cameras calibration) is absolutely necessary for the successful processing the images.

The purpose of the experiment described in this article – to define how the photo camera calibration parameters (optics errors) influence the processing of images. For such a geometric model, photo triangulation had to be made and the results and precision of stereo digitalization analysed.

### 2. Camera calibration process

Normally the camera calibration process can be divided into several stages: test-field target images making, processing of the resulting images and estimation of the camera parameters.

For the calibration of camera the images of the test-field should be made at different camera positions and angles (Fig. 1).



Fig. 1. Test-field for the camera calibration

For the successful processing of images the following is necessary:

- Small intersection angles between the viewing rays in triangulation of the test field target should be avoided. It is important to take the image pairs from different position in relation to the test field.
- A stable adjustment of the principal point coordinates (interior orientation) requires a rotation of the camera about optical axis (or rotation of the test field).

This process is very important for achieving a suitable geometric configuration. Otherwise the software does not check the geometry. Unsuccessful configuration results in unreliable calibration data. The Fig. 2 shows a proposal for taking test-field images with a stable geometry.

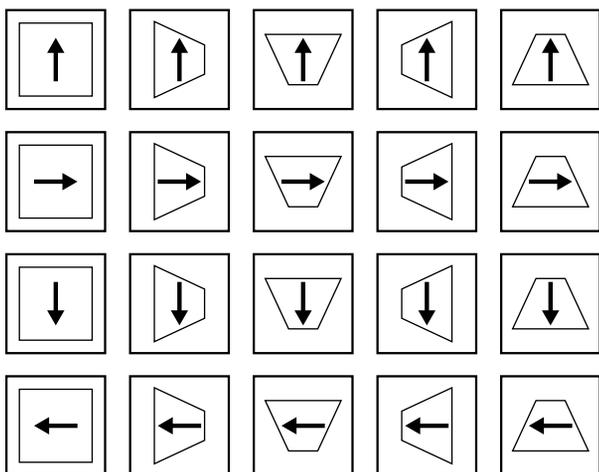


Fig. 2. Position for taking test fields images with a stable geometry

For processing the test-field images special *Tcc* software was developed at the Laboratory of Photogrammetry of University of Bonn. The software consists of the following modules (Abraham 2004):

- *TccAdj* (adjustment);
- *TccImg* (images importing);
- *TccLut* (processing results).

The software creates an approximate 3D model of the points marked on the test-field. The coordinates are required to number the targets, that are detected in the image and to set up correspondences between the targets in different images. The numbers of the points are always

unique, otherwise the result of the bundle adjustment alignment will be inadequate. The accuracy of the result can be defined by the standard deviation and variance factor  $\sigma_0$  of test-field points determination, which should be smaller than 2.0. The value of the factor can be determined after adjusting of the triangulation.

After the successful calculations of camera lens errors, which are described by 6 parameters:  $A_1, A_2, A_3$  – radial symmetric distortion,  $B_1, B_2, B_3$  – radial asymmetric distortions, are tabled in the \*.lut file (Marzan, Karara 2003; Läbe, Förstner 2004).

These parameters will later be used for correction of the camera optical errors in images.

The correction of distortion according to the calibration results can be performed using special *Tcc DistortionCorrect* software (created at University of Bonn), which corrects the images itself, use the calibration results during the further processing images (if such a feature has been included in the software) (Läbe, Förstner 2004).

### 3. Calibration of digital Canon EOS 350D camera

Calibration of photo camera used for the described project was performed at Photogrammetric Institute of University of Bonn, using *Tcc* software in 2006. The specifications of Canon Eos 350D digital camera are shown in Table 1.

Table 1. Characteristics of Canon EOS 350D digital camera

Characteristics	Value
Focal length, mm	20
Resolution, pixel	8 mln.
One pixel size, $\mu\text{m}$	6.4×6.4
Image size, mm	22.2×14.8
Image size, pixel	3456×2304
Format of images	JPG, RAW

Calibration was performed using a test-field with the mark points (Fig. 1) (Sužiedelytė-Visockienė 2007). Calibration results and precision parameters of camera are following: principal distance ( $c$ ) – 3149.66 pixel; scale of images ( $S_{xy}$ ) – 0.99; definition of principal point in the images  $x_0$  – -12.32 pixel,  $y_0$  – 3.22 pixel; radial symmetrical distortion  $A_1$  –  $-2.39 \times 10^{-01}$  pixel,  $A_2$  –  $1.16 \times 10^{-01}$  pixel; radial asymmetrical distortion  $B_1$  –  $-4.78 \times 10^{-02}$  pixel,  $B_2$  –  $3.72 \times 10^{-02}$  pixel; rate of precision ( $\sigma_0$ ) – 1.4563 pixel.

Investigation in how do cameras calibration parameters influence creation of geometric model, calculation of photo triangulation and digitalization of model are described in the next chapter.

### 4. The experiment

Triangulation is highly important while making maps or plans by the photogrammetric methods and is based on the creation of geometric model. Photo triangulation can be created by means of dependent and independent model methods. In case of the first method the model obtained in the photogrammetric coordinate system is being reduced to the geodetic coordinate system. For this purpose the mark points are placed on the researched area or on the object and the coordinates of those marks are being determined by means of geodetic instruments. In case of the

second method, every photogrammetric model is creating independently, i.e. without any connecting to the geodetic coordinates (Skeivalas, 2008). At the stereo-pair points coordinates are measured and calculated, image orientation elements adjusted. Several independent models then are connected to the general network by overall tie points, using the spatial linear conformal transformation formulas. All these tasks can be performed by the digital photogrammetric *PhotoMod* (Russia) system (2007).

Digital *PhotoMod* photogrammetric system consists of such modules:

- *PhotoMod Montage Desktop*, used for creating the projects and connecting it to other modules;
- *PhotoMod AT* – measurement of points and creation of the geometric model;
- *PhotoMod Solve* – calculating of photo triangulation;
- *PhotoMod Stereo Draw* – stereo digitalization;
- *PhotoMod DTM* – creation of digital terrain model;
- *PhotoMod Mosaic* – creation of orthophotomap.

For experiment 2 overlapping images of central facade of Arnionys mansion-house in Molėtai were chosen. Images were taken by *Canon EOS350D* photo camera (Fig. 3).

The correction of images was done by the *Tcc DistortionCorrection* software, which was specially designed for correction of images errors emerging from the cameras system faults (optic and electronic), i.e. distortion and shift of the principal point in images. Then the results of camera calibration performed by the *Tcc* software (\*.lut format) are needed (Chapter 3). The digital sizes of the experimental images have changed after the correction (Table 2).



Fig. 3. Central facade of Arnionys mansion-house

Table 2. Sizes of digital images after correction

Image No.	Size of images, Mb		Alteration %
	Original	Corrected	
0005	2.75	3.60	30.9
0006	2.90	3.76	29.6

The results presented in Table 2 show that the digital sizes of images increased approximately by 30% after the correction, though the resolution of images have not changed.

Using the *Montage Desktop* module of software *PhotoMod 2* projects (Arnionys mansion-house) for the experiment were created. In the first one the images without the correction of photo camera optics errors (distortions) were used, in the second – the corrected images. The geometric models were created by the *PhotoMod AT* module using the same geodetic and tie points in the images (Fig. 4).

The results of precision rate of created geometric model are shown in Table 3.

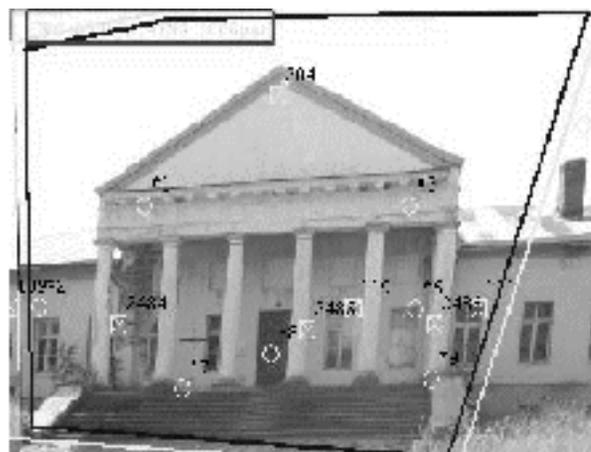


Fig. 4. Geometric model of central side of Arnionys facade

Table 3. Precision rate of model

Images	Max. error of point parallax* in $\mu\text{m}$	RMS** of point measurement in $\mu\text{m}$
Non-corrected	5.8	3.2
Corrected	3.9	1.6

\* transversal discrepancies of the same points in images.

\*\* RMS – root mean square error.

The size of a single pixel is  $6.4 \times 6.4 \mu\text{m}$ . In case of the corrected images (the optics errors being evaluated) the parallax of point measurement decreased by 68% and RMS – 50%.

Using the *PhotoMod Solve* module the calculation of photo triangulation of geometric model based on 7 points of model were made. The coordinates of these points were known from the geodetic measurement. Differences in coordinates of the processed points are in Table 4.

In the above table:  $E_{xy}, E'_{xy}$  – the  $x$  and  $y$  coordinates differences between the photo triangulation and geodetically measured points;  $E_z, E'_z$  – the  $z$  coordinate differences between the photo triangulation and geode-

**Table 4.** Coordinate deviations of photo triangulation points

Points No.	Non-corrected images		Corrected image	
	$E_{xy}$ , m	$E_z$ , m	$E'_{xy}$	$E'_z$
109	0.055	0.132	0.007	0.012
119	0.043	0.164	0.003	-0.033
121	0.029	0.115	0.007	0.012
204	0.055	0.000	0.002	0.004
2484	0.114	-0.161	0.006	-0.009
2485	0.004	-0.076	0.003	0.002
2486	0.080	-0.173	0.001	0.012
Rate of precision, m				
Average	0.054	0.117	0.004	0.006
Max. error	0.114	-0.173	0.007	-0.033
RMS	<b>0.063</b>	<b>0.130</b>	<b>0.005</b>	<b>0.015</b>

tically measured points. In that case the geodetic measurements (performed by total station) are considered as the reference ones.

The results of the photo triangulation increased by 5–30%, in case of using the corrected images in the project.

Using the *PhotoMod Stereo Draw* module, the stereo digitalization of both projects was made. The results of stereo digitalization are shown in Fig. 5.

To evaluate the results of photo digitalisation, differences of the same 24 points in case of both projects were calculated. The deviations and the root mean square (RMS) of the measurements were calculated. The calculations are in Table 5.



**Fig. 5.** Stereo digitalization data of mansion-house in Arnionys (continuous lines show the data from non-corrected images, dotted line – the corrected ones)

**Table 5.** Deviation of stereo-digitalization points in the projects

	Rate of precision, m		
	$E_x$	$E_y$	$E_z$
Min. dev.	0.016	- 0.029	- 0.007
Max. dev.	0.195	- 0.316	0.091
Average	0.108	- 0.149	0.043
RMS	0.125	0.201	0.058

In Table 5  $E_x, E_y, E_z$  –  $x, y$  and  $z$  coordinate differences of stereo digitalization points in case of both projects. The mean coordinate deviations of points are - 0.15–0.11 m, RMS – 0.06–0.20 m.

Using the data obtained from the second (in which the corrected images were processed) the drawing of the central part of facade of Arnionys mansion-house were made (Fig. 6) by AutoCad software.



**Fig. 6.** 2D drawing of the central part of the Arnionys mansion-house façade using photogrammetric data

**5. Conclusions**

Generalising the obtained results, it might be stated that in case of a precise photogrammetric works it is absolutely necessary to include correction of the optical errors of the camera calculated during calibration into the images processing, or to use the images already corrected by a special software.

According to the described research, it was determined that:

1. The optical errors of the digital camera are quite small, nonetheless they have a great influence on the image processing.
2. After the correction due to the errors of camera optics the digital volume of the images increased up to 30 %, though the resolution (the number of smallest point elements – pixels) remained the same.
3. After the creation of the geometric model by means of the *PhotoMod AT* software module, it was determined, that in case of using the corrected images, the radial discrepancies of the geodetically determined (reference) and the tie points decreased by 68% and the RMS – 50 %.
4. After the calculations of photo-triangulation (*PhotoMod Solve* module) by the corrected images for the project, the RMS of the points me-

asurement (identification) decreased by 5–30%, compared to the results obtained using the non-corrected images.

5. The stereo-digitalisation of the facade of the architectural object showed, that in case of the mean coordinate difference of the same digitalised points in case of 2 projects (using the corrected and non-corrected images) is up to 0.15–0.11 m, which is a quite high value, showing that the camera calibration is absolutely essential in case of photogrammetric measurements.

## References

- Abraham, S. 2004. *Tcc – a software for test field based self-calibration of multi-camera-systems*. Institute für Photogrammetrie, Universität Bonn. 39 p.
- Marzan, G. T.; Karara, H. M. 2003. A computer program for direct linear transformation solution of the collinearity condition, and some applications of it, in *Proceedings of the Symposium on Close-Range Photogrammetric Systems*. Falls Church, VA: American Society of Photogrammetry, 420–476.
- Läbe, Th; Förstner, W. 2004. *Geometry stability of low-cost digital consumer cameras*. Institute für Photogrammetrie, Universität Bonn, Commission I/2, 7 p.
- Skeivalas, J. 2008. *GPS tinklų teorija ir praktika* [Theory and practice of GPS networks]. Vilnius: Technika. 287 p.
- Sužiedelytė Visockienė, J. 2007. Skaitmeninės matuojamosios fotokameros kalibravimo parametrų įtaka nuotraukos transformuojant į plokštumą [Definitions influence on Digital Photocamera parameters of calibration on transformation of photos in the plane], *Geodezija ir kartografija* [Geodesy and Cartography] 33(1): 26–30.
- PhotoMod 4.3. User Manual. Racurs, Moscow, 2007. Available from Internet: <<http://www2.racurs.ru/docs/en/general.pdf>>.

---

**Jūratė SUŽIEDELYTĖ-VISOCKIENĖ.** Doc. dr Vilnius Gediminas Technical University. Dept of Geodesy and Cadastre (Ph +370 5 274 4703, Fax +370 5 274 4705).

The PhD thesis defended in 2003. Author of more than 15 research papers.

Research interests: digital photogrammetry, land management.

---

**Domantas BRUČAS.** Dr Vilnius Gediminas Technical University. Dept of Geodesy and Cadastre (Ph +370 5 274 4703, Fax +370 5 274 4705).

The PhD thesis defended in 2008. Author of 11 research papers.

Research interests: development and investigation of comparator for angular measurements, automation of the processing the measurement results.