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EXAMINING THE IMPACT OF RECORDING LONG-SERIES IMAGES TAKEN FROM NON-METRIC CAMERAS ON OPTIMISATION OF MODELLING PROCESS AND 3D VISUALISATIONS

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Summary

In spite of the diversity of methods used in acquiring data images and later in the modelling process and spatial visualisation it is worthwhile to seek for alternative methods of optimizing the applied technique and processing method. Adopting costly solutions is not always necessary. For the purposes of terrain analysis and local assessments of landscape the author suggest to use the modelling method based on recording series images taken by non-metric cameras, guaranteeing economical, technically optimal and accurate solution of the problem. This claim is proven by the accuracy analyses of generated spatial visualisations and the results of calibration of chosen non-metric cameras.

The study confirmed the consistency of the results of control measurements – carried out by means of analyses of calibration reports in chosen non-metric cameras and an exemplary object's spatial model created by a separate software – with the predictions made in the stage of theoretical considerations.

Keywords

recording of long-series images • non-metric cameras • calibration • 3D modelling

1. Introduction

High development dynamics of image information systems together with Internet as a means of communication and source of information is still on the rise [Gryboś et al. 2013].

Constantly improved non-metric cameras are more and more popular and in some well-grounded cases they can replace costly, more professional devices. New solutions for generating 3D models in the cloud computing environment emerge, allowing for the data processing largely without the participation of the project's author. The activity of famous firms like Google, Microsoft and Autodesk considerably contribute to the development of this domain.

This paper is aimed at presenting the results of a study of calibration of chosen non-metric cameras and outcomes of an accuracy analysis of a spatial model generated by these cameras in two modes of taking pictures: single shot mode and continuous one. The goal of this comparison is to optimise functioning of the cameras in the process of spatial visualisation, and to broaden the scope of discussion on the application of long-series mode.

The methodology of modelling based on series or long-series record of images can contribute significantly to improvement of quality and accuracy of objects' models created by applications based on algorithm of scale invariant feature transform (SIFT).

2. Research methodology

As the author's study showed, good results in improvement of accuracy of 3D models in applications based on SIFT algorithm can be achieved by using continuous and long-series technique. That is why in the presented research (one of many studies of this kind) on calibration of non-metric cameras by means of pictures of a test board, the use of continuous mode was aimed at demonstrating its superiority – practical and accuracy-wise – over single shot mode. This superiority results from the fact that in the continuous recording the exposition time of photodetectors is regulated only electronically by reading with a definite frequency of accumulated electric charges. That is why this mode does not effect image orientation.

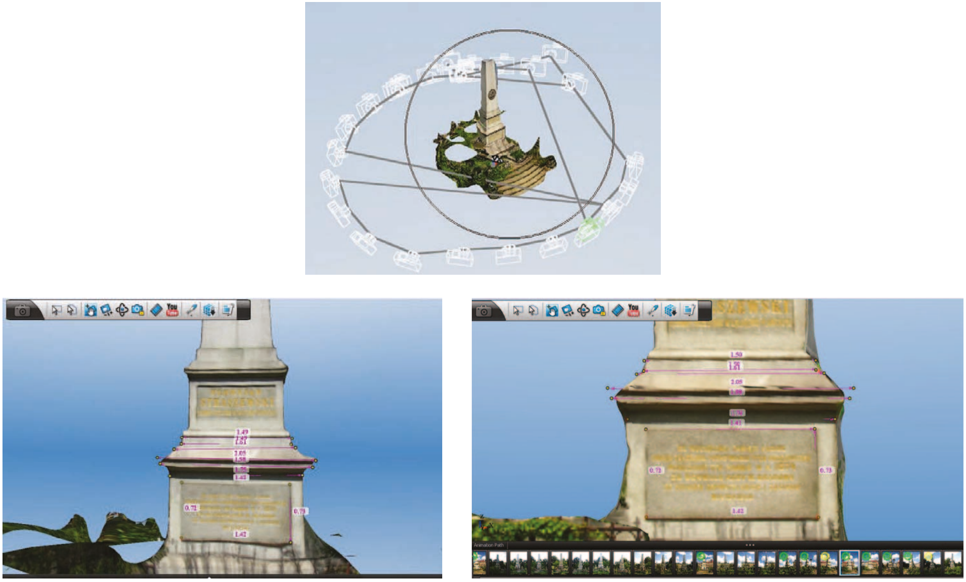
Long-series image recording technique is an extension of continuous mode with the following conditions:

- the pictures are taken in relatively long series (e.g. a few hundred shots),
- the memory card of the camera must be sufficiently large (it follows from the first condition),
- the image recording is regular (with a fixed time interval) and sufficiently fast,
- the images are best recorded in a series as "frozen", to avoid blur.

In case of single shooting mode the photo-mechanics of the camera plays an essential role, which impairs image stability. Among conditions that significantly influence the zoom lens stability of a digital (non-metric) compact camera is the movement of zoom lens – sliding and rotary motion while taking single pictures, when the uniqueness of the lens position causes instability of image distance.

That is why recording of images was done with camera calibration and an exemplary object's model was generated (Figure 1) together with its measurement in the field – in variants that enable the discussion of results, developed by software ensuring simple and clear accuracy analysis.

The study of models created by using long-series image recording indicate that they are more accurate, have less distortions, contain more than twice as many correct results in a set of control measurements and are faster to record than the method based on a single shot mode.



Source: author's study

Fig. 1. Positions of the Canon camera (above) and measurement of control tie distances in modelling from series pictures (left) and single ones (right). The exemplary visualisation of the Florian Straszewski monument in Kraków was created by 123D Catch software. In visualisations made from single shots distortions are more visible than in the continuous mode

Another difference in the results between these two modes of recording images lies in determining the orientation of pictures and positions of the camera. In a long-series method the configuration of images was correctly determined. In the second method the order of images was incorrect even when the corresponding points on the subsequent pictures have been manually determined, which has been shown in earlier studies of modelling and spatial visualisations carried out by the author [Jankowicz 2015].

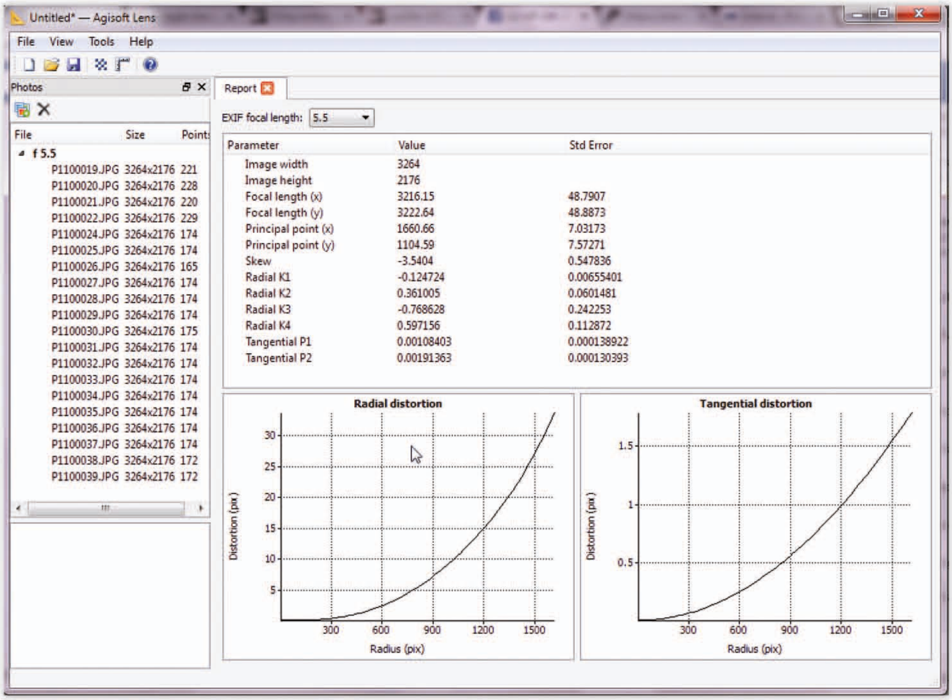
The calibration of the camera is a procedure by which interior orientation elements (IOE) can be determined with a specific error, the value of which shows the dispersion in their determination. The results of studies of selected cameras are presented below.

The results of calibration of chosen non-metric cameras include five picture sessions of a calibration board in Agisoft Lens software.

Generally, comparison of results of series recordings of images (Figure 2) and single ones (Figure 3) proved that in the first method the lower standard errors regarding the following parameters:

- focal length (x), (y),
- coordinates of picture's principal point (x), (y),

had better stability in the process of taking pictures.



Source: author's study

Fig. 2. The results of an exemplary calibration of a Panasonic DMC-FS3 camera – series pictures. Values of standard errors for focal lengths and principal points are visibly lower than in Figure 3

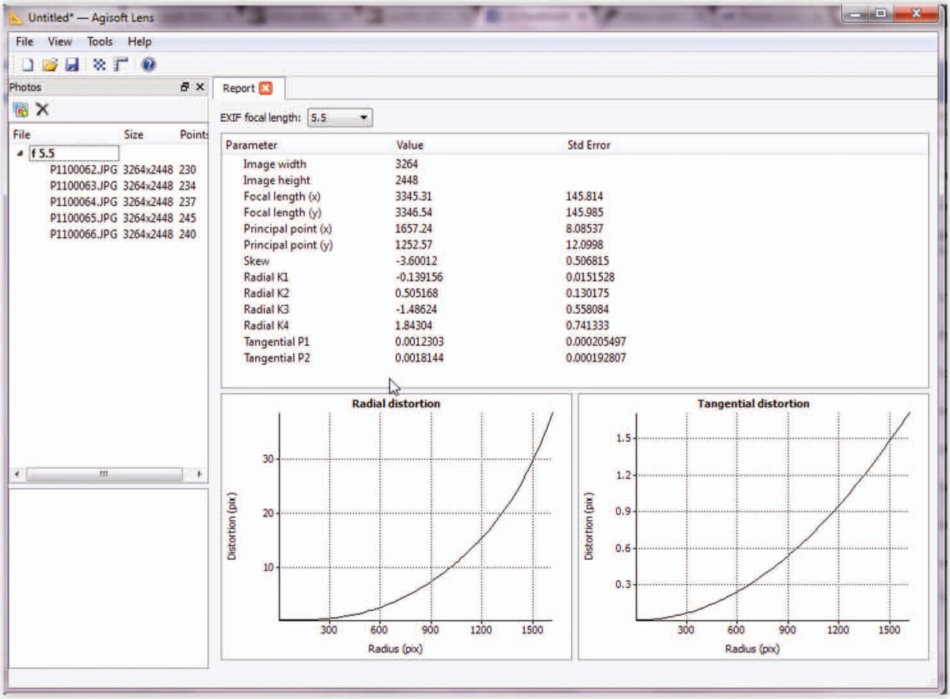
This advantage translates further into accuracy parameters of an object's 3D model, generated in the next stage from the series pictures.

The report of calibration (made by Agisoft Lens software) of the Panasonic DMC-FS3 camera presented above includes estimated values of specific parameters, some of which with their errors (Figures 2 and 3):

- image width / height [pix],
- horizontal and vertical focal length (x), (y) [pix],
- coordinates of principal point (x), (y) [pix],
- radial distortion value K1, K2, K3, K4 and tangential distortion value P1, P2 [pix],
- skew of axes X and Y.

Next, the calculations determine the transformation of coordinates in a local configuration of a camera to a pixel coordinates in an image frame.

Local system of coordinates of a camera starts in the middle of a projection. *Z* axis takes a direction of look, X axis points to the right, Y axis – downward.



Source: author's study

Fig. 3. The results of calibration of Panasonic DMC-FS3 camera – single shots. A big difference of errors of determining focal length and little difference in its value F(x, y) is particularly noteworthy when comparing results shown in Figure 2 and 3 for both modes of recording pictures. Similar observation applies to determining the position of an image's principal point O(x, y)

The system of coordinates starts in a left upper image pixel, precisely in its middle, with coordinates (0.5, 0.5). Y axis of an image system coordinates points to the right, Y axis – downward.

For a given point M (X, Y, Z) in a local coordination system of a camera, predicted coordinates in an image frame can be calculated by the following equations:

$$x = X / Z$$

$$y = Y / Z$$

$$x' = x(1 + K_1r^2 + K_2r^4 + K_3r^6) + P_2(r^2 + 2x^2) + 2P_1xy$$

$$y' = y(1 + K_1r^2 + K_2r^4 + K_3r^6) + P_1(r^2 + 2y^2) + 2P_2xy$$

$$u = c_x + x'f_x + y'skew$$

$$v = c_y + y'f_y$$

where:

$r = sqrt(x^2 + y^2)$,

X, Y, Z – points' coordinates in the local coordinates of the camera,

(u, v) – predicted coordinates of points in the system of coordinates of an image [pix],

(f_x, f_y) – focal lengths,

(c_x, c_y) – principal point coordinates,

K_1, K_2, K_3 – coefficients of radial distortions,

P_1, P_2 – coefficients of tangential distortions,

Skew – skew coefficient of axis x and y.

Moreover, graphs are presenting values (in pixels) of radial and tangential distortions, as a relation of distortion on its radius (Brown's model).

Similar research was carried out for other non-metric cameras (Sony Cybershot DSC-T-5, Canon EOS 400D), confirming that standard errors in determining horizontal focal length F_x and vertical F_y and coordinates of principal point O (x, y) are significantly lower in series pictures than in single ones.

Comparison of the results is presented in Table 1.

Table 1. Comparison of the results of calibration of chosen cameras with special emphasis on standard errors of focal lengths F(x)err / F(y)err and standard errors of principal point coordinates O(x)err / O(y)err. In brackets values of principal parameters: focal lengths F(x) / F(y) and coordinates of principal point O(x) / O(y), referring to these errors. The values are expressed in pixels.

Camera	Continuous mode	Single shot mode
	F(x)err / F(y)err O(x)err / O(y)err	F(x)err / F(y)err O(x)err / O(y)err
Panasonic FS3	48.79 / 48.88 7.03 / 7.57 (3216 / 3223) (1661 / 1105)	145.81 / 145.98 8.09 / 12.10 (3345 / 3346) (1657 / 1253)
Sony DSC-T5	125.29 / 125.09 5.95 / 4.03 (2932 / 2931) (1338 / 814)	196.86 / 196.60 6.47 / 4.27 (2915 / 2914) (1339 / 814)
Canon EOS 400D	0.017 / 0.032 6.35 /1.63 (1130 / 1124) (2003 / 1284)	92.10 / 91.88 6.10 / 12.33 (3596 / 3597) (2007 / 1271)

Source: author's study

3. Conclusions

The calibrations of chosen non-metric cameras showed that the continuous mode of recording pictures is more accurate. The standard error values of focal length and position of the principal point of a picture in all continuous mode sessions have lower values than in single shot sessions.

Moreover, on the basis of the research carried out in the field [Kwoczyńska 2013] and with the help of 123D Catch software, it was confirmed that models and 3D visualisations from terrestrial pictures (Figure 1) and aerial ones, taken by unmanned aerial vehicles (UAV) by a long-series image recording method, are characterized by greater accuracy, which is proven by studies carried out by others [Litwin and Piech 2013, Litwin and Pijanowski 2013].

Apart from that, series method of recording, in comparison with the single shot one is: faster, a generated model has less distortions, "Error-free" measurements of a generated model is 70% of database in continuous mode and 30% in single shot mode.

Therefore, having the above results in mind, one can say that 3D visualisations generated from series of pictures have better accuracy parameters, which is also confirmed by the outcomes of calibration chosen non-metric cameras.

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