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SMALL FORMAT DIGITAL PHOTOGRAMMETRY FOR APPLICATIONS IN THE EARTH SCIENCES

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ABSTRACT:

Photogrammetry is often considered one of the most precise and versatile surveying techniques. The same camera and analysis software can be used for measurements from sub-millimetre to kilometre scale. Such a measurement device is well suited for application by earth scientists working in the field. In this case a small toolset and a straight forward setup best fit the needs of the operator. While a digital camera is typically already part of the field equipment of an earth scientist, the main focus of the field work is often not surveying. Lack in photogrammetric training at the same time requires an easy to learn, straight forward surveying technique. A photogrammetric method was developed aimed primarily at earth scientists for taking accurate measurements in the field minimizing extra bulk and weight of the required equipment. The work included several challenges. a) Definition of an upright coordinate system without heavy and bulky tools like a total station or GNS-Sensor, b) optimization of image acquisition and geometric stability of the image block, c) identification of a small camera suitable for precise measurements in the field, d) optimization of the workflow from image acquisition to preparation of images for stereo measurements, e) introduction of students and non-photogrammetrists to the workflow.

1. INTRODUCTION

Digital photogrammetric work stations are easily accessible to non-photogrammetrists these days. In some cases add-ons to GIS and other software products are marketed directly for use by earth scientists. In order to increase the awareness of close range photogrammetry to enable wider and wiser applications by earth scientists, simple entry level methods can help to increase the basic understanding of close range photogrammetry and to prepare earth scientists for more advanced application of this science. The main purpose of field work of an earth scientist is typically not surveying. Working abroad in remote locations under adverse conditions may be considered the normal case. Therefore, the extra equipment for a field surveying technique should be reduced to the bare minimum, but still allow for accurate measurements and follow established methods applied in photogrammetry. Although the basics on photogrammetry can be found in many textbooks as well as software manuals, sensible combination of methods and field tests are required to optimize a workflow for earth scientists. In the following we will elaborate on previous work in this direction (Rieke-Zapp et al, 2009) and present an improved workflow. Shortcoming of the methodology presented by Rieke-Zapp et al. (2009) were the geometric stability of small format cameras, the definition of an upright coordinate system and the dependency on costly pre-processing software for image orientation. The workflow involves image acquisition in the field, input of imagery in a digital photogrammetric workstation and orientation of imagery for further analysis, i.e. stereo viewing or image correlation. Camera calibration can be added to the workflow as easy to use, low cost software is available for this task.

Results from field tests were used for a rigorous accuracy assessment of small format digital cameras compared to measurements taken with a total station. Small format digital cameras have received a lot of attention from the UAV community as they are small and light enough to be carried by UAVs. Recommendations regarding geometric stability and accuracy accomplished in object space apply to UAV applications as well.

2. WOKLFLOW AND ACCURACY ASSESEMENT

2.1 Camera calibration

Calibration of the interior geometry of a camera is a prerequisite for photogrammetric analysis of images from consumer cameras. This procedure also includes the calculation of additional parameters accounting for lens distortion. Calibration results of several small format digital cameras were compared to check for the influence of temperature and time on the calibrated parameters (Figure 1). The cameras were calibrated with Photometrix Camera Calibrator software (Photometrix, 2008). This software provides an automated workflow for camera calibration and all significant calibration parameters can easily be applied in ERDAS LPS 9.3 software (ERDAS, 2008) that was used later for image orientation and further image analysis.

While temperature had no visible effect on the position of the principle point, calibrations over a one year time period revealed that the position of the principal point is far from stable for all tested cameras. This does not come as a surprise as these cameras were not designed for metric application and the lens is retracted every time the camera is switched off. Results for the Sigma DP1 and DP2 show less creep of the principal point than for the Ricoh GR digital where the position of the principal point can move up to 40 pixels between consecutive

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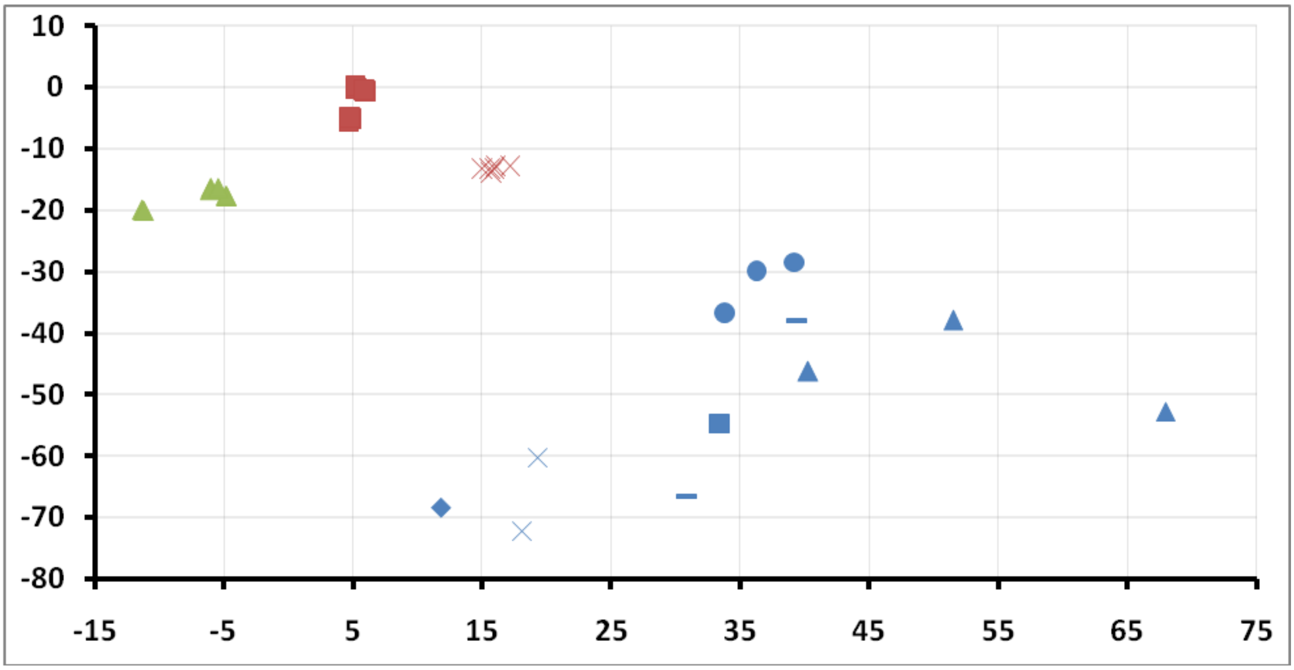

Figure 1. Principle point offset in pixels for Sigma DP2 (green), Sigma DP1 (red) and Ricoh GR digital (blue) for different calibrations. Calibrations cover a time span of 90 (Sigma DP2) to 300 days (Sigma DP1, Ricoh GR digital). The same symbol was chosen for calibrations of the same day in case of the Ricoh GR digital. Two symbols were chosen for the Sigma DP1 representing two clusters of principle point position.

calibrations. The small pixel pitch of the Ricoh camera amplifies the effect of mechanical movement compared to the Sigma cameras with more than 3-times larger pixel pitch (Table 1).

Simple comparison of calibrated parameters is not a good indicator for accuracy that can be accomplished in object space.

Images of a climbing wall with dimension of approximately 6 x 5 x 7 m^3 were taken to test the accuracy of the cameras in object space. Five images were taken with each camera. Image orientation was performed based on the known location of three points signalized in object space. In addition to the three points eight reflective targets were distributed in the area of interest that were introduced as tie points in the photogrammetric adjustment which was performed with ERDAS LPS 9.3 (ERDAS, 2008) software. The eight tie points were also measured with a total station with superior accuracy from four different locations. Calculating the Euclidean distances between the eight points and comparing results from the total station to photogrammetric measurements allowed calculating the discrepancy in length measurements. This procedure was applied in analogy to VDI/VDE 2634 (1) (2002).

Best results were accomplished with the Sigma DP2 camera. The maximum length measurement error with the most recent calibration was 5 mm. Working with older calibrations, the maximum length measurement error became 7 mm at most (Figure 2a). Results for the Sigma DP1 revealed a maximum length measurement error of 10 mm for the most recent calibration and 16 mm for a calibration almost one year old (Figure 2b). The Ricoh GR digital produced a maximum length measurement error of 24 mm with the most recent and 61 mm with a one year old calibration (Figure 2c). While results for the two Sigma cameras are acceptable even in case of older calibrations, the Ricoh camera performs at a significantly lower level.

Re-calculation of parameters of interior orientation in the bundle block adjustment in ERDAS LPS reduced the maximum length measurement error to 11 mm for the Ricoh. Introduction of additional parameters in this calibration did not improve results – accuracy in object space was actually reduced to a maximum length measurement error of 18 mm. This was probably due to over-parameterization in the small block of imagery lacking strong geometric stability. This is in accord with observations made previously (Rieke-Zapp et al., 2009). Re-calibration of the parameters of interior orientation in ERDAS LPS had little effect on the maximum length measurement error of the Sigma DP1 and DP2. The resulting maximum length measurement errors were less than 10 mm in all cases. This states a significant improvement only for the one year old calibration of the Sigma DP1.

Camera	Ricoh GR digital	Sigma DP1	Sigma DP2
Sensor size (mm)	7.182 x 5.386	20.592 x 13.728	
Pixel count (mm)	3264 x 2448	2640 x 1760	
Pixel pitch (mm)	0.0022	0.0078	
Field of view (°)	64 x 50	64 x 45	47 x 32
Weight (kg) ready to go	0.200	0.280	0.290
Focal length (mm)	5.9	16.6	24.2

Table 1. General specifications of the three cameras. The Sigma DP1 and DP2 share the same sensor.

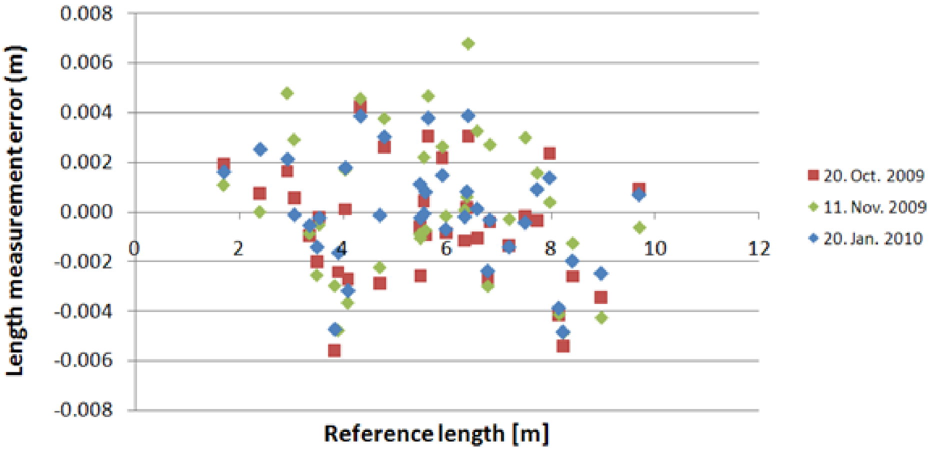

Figure 2a) Length measurement errors for Sigma DP2 based on three different calibration dates. Images were taken 20. Jan. 2010.

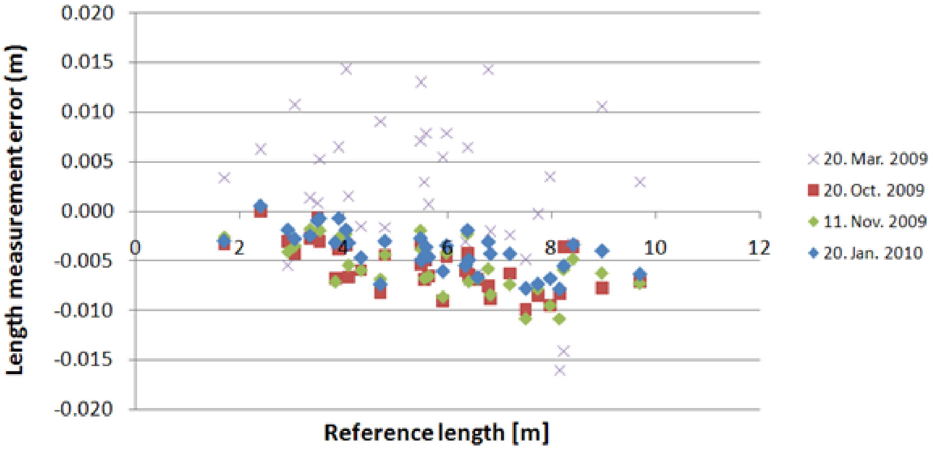

Figure 2b) Length measurement errors for Sigma DP1 based on four different calibration dates. Images were taken 20. Jan. 2010.

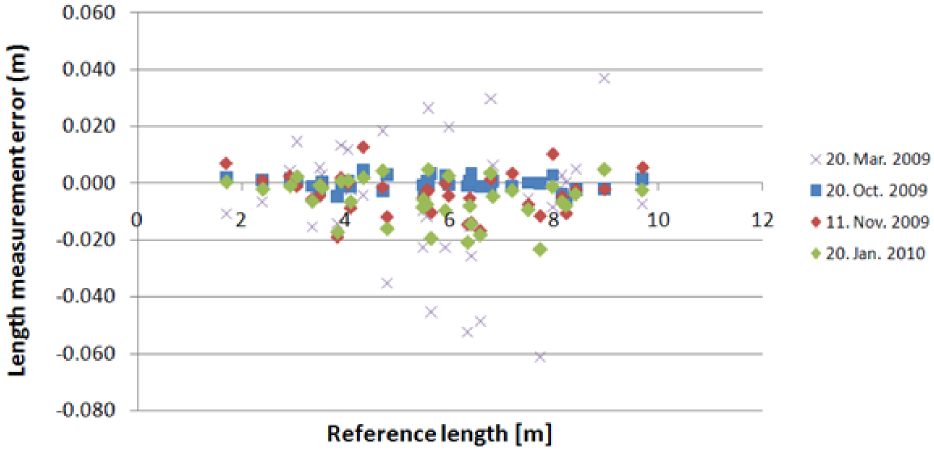

Figure 2c) Length measurement errors for Ricoh GR digital based on four different calibration dates. Images were taken 20. Jan. 2010.

2.2 Measurements on location

The local coordinate system was referenced by three points. Ping pong balls were used as target points because they have a well defined diameter (40 mm), are well rounded and weigh as little as 2.7 g (ITTF, 2009). These spherical targets will appear as circles in images and measuring of distance between them for spatial reference in object space is straight forward. Working with a Leica Disto D3 laser distance meter allowed measuring distances as well as the vertical angle between ping pong balls. This allowed fixing the resulting coordinate system to the horizontal. Transformation (Helmert transformation with scale parameter fixed to 1) of the resulting coordinates generated from imagery into the coordinates system defined by the total station, resulted in a maximum rotation around the horizontal axes of 0.18°, 0.18° and 0.36° for the Sigma DP1, Sigma DP2 and Ricoh GR digital, respectively, based on the original calibration. The result for the Ricoh GR digital improved slightly to 0.34° in case the interior orientation was calibrated in the bundle adjustment. These results compare quite favourable to typical field measurements taken by earth scientist with compass and inclinometer. Orientation towards compass North requires a compass measurement in addition. Precise measurement of distances as well as horizontal and vertical angles is possible with a modified version of the Leica Disto A3 (Heeb, 2008). Generation of a 3-dimnesionl coordinate system with arbitrary origin from Disto measurements is straight forward. The precision of distance measurements (1 mm) is far superior to the angular measurements (0.3°) which should be taken into account for proper propagation of error of Disto measurements.

It is advisable to place ping pong balls in such way that the X-axis runs through two ping pong balls – this eases the definition of approximate coordinates for all point – and to take images for stereo viewing perpendicular to the X-axis.

All tests are based on five images taken in the field. Two converging images were taken from far left and far right and three images were taken with 60 to 80% stereo overlap in normal orientation for stereo viewing of the scene.

2.3 Image orientation

Image orientation in ERDAS LPS software was straight forward. Stereo viewing is only possible in this software for the aerial image orientation (camera pointing along the Z-axis). This requires a rotation of the calculated coordinate system to represent a right-hand system with the Z-axis pointing towards the camera stations.

Rotation of the two convergent images around the optical axis for a re-calibration of the principal point in ERDAS LPS software is advisable to improve accuracy in object space for cameras with unstable interior geometry, i.e. Ricoh GR digital.

3. DISCUSSION AND FUTURE WORK

Although small format digital cameras appeal to a wide range of applications, the geometric accuracy of these cameras limits the precision that can be accomplished in object space. Here we report on field results of three cameras with fixed focal length. The two Sigma cameras with notably larger sensor dimensions and pixel pitch than typical small format cameras yield accurate results even with several month old calibrations.

The size of an object that can be covered by a couple images is limited to pixel resolution in object space. Sufficient detail will be visible for volumes up to 20 x 20 x 20 m^3. Although the Ricoh GR digital sensor has a larger pixel count than the Sigma cameras, the amount of detail that can be recognized in the imagery was approximately the same.

The ever growing market of small format digital cameras provides new camera designs at very short intervals. This makes older, proven designs often obsolete within a year, and provides new candidates for field application on a regular basis. The general trend towards even smaller sensors, increased pixel count and more technical features like zoom lenses is of no advantage for metric applications of these cameras.

The same type of cameras represents the “eyes” of lightweight UAVs. Constant evaluation may help to identify the camera with optimum geometric properties for this application as well.

Mechanical fixation for further improvement of small format digital cameras is difficult, as the lens retraction mechanisms is part of the camera design. Dropping additional parts like flash, display and replacing the camera housing may even allow for an extremely lightweight camera that is easily carried by UAVs.

Future work will include application of the modified Disto A3 for horizontal orientation of the coordinate system and identification of additional cameras suitable for this work. Introduction of students and non-photogrammetrists to the method will be continued. Preparation and measurements in the field takes approximately 10 minutes. Definition of a 3-dimensional coordinate system and image orientation took approximately 20 minutes after a little training.

The extra weight that has to be added to the backpack of a field scientist is less than 165 g assuming that the digital camera also serves as a tool for documentation of outcrops and field sites. The total weight of all components including the camera adds to approximately 425 g.

4. REFERENCES:

Heeb, B., 2008. Paperless Caving - An Electronic Cave Surveying System. Paper presented at the 4th European Speleological Congress. http://paperless.bheeb.ch/download/PaperlessCaving.pdf [Accessed 28th April 2010]

ITTF (International table Tennis Federation), 2009. ITTF handbook 2009/2010. http://www.ittf.com/ittf_handbook/ittf _hb.html [Accessed 28th April 2010]

ERDAS, 2008. *LPS Project Manager User’s Guide*. ERDAS, Norcross, Georgia, USA. 440 p.

Photometrix, 2008. Users Manual for Camera Calibrator V1.0, Australia. 18 p.

Rieke-Zapp, D., R. Rosenbauer, F. Schlunegger, 2009. A photogrammetric surveying method for field application. *The Photogrammetric Record*, 24(125), pp. 5-22.

VDI/VDE 2002: VDI/VDE Richtlinie 2634 Part 1, Optical 3D measuring systems, imaging systems with point-by-point probing. Beuth, Berlin. 10 pages.