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# Small format digital photogrammetry for applications in the earth sciences

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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.
Wooden spheres were used as target points in the field. They were more rugged and available in different sizes than ping pong balls used in a previous setup. Distances between three spheres were introduced as scale information in a photogrammetric adjustment. The distances were measured with a laser distance meter accurate to 1 mm (1 sigma). The vertical angle between the spheres was measured with the same laser distance meter. The precision of the measurement was 0.3° (1 sigma) which is sufficient, i.e. better than inclination measurements with a geological compass. The upright coordinate system is important to measure the dip angle of geologic features in outcrop. The planimetric coordinate systems would be arbitrary, but may easily be oriented to compass north introducing a direction measurement of a compass. Wooden spheres and a Leica disto D3 laser distance meter added less than 0.150 kg to the field equipment considering that a suitable digital camera was already part of it.
Identification of a small digital camera suitable for precise measurements was a major part of this work. A group of cameras were calibrated several times over different periods of time on a testfield. Further evaluation involved an accuracy assessment in the field comparing distances between signalized points calculated form a photogrammetric setup with coordinates derived from a total station survey. The smallest camera in the test required calibration on the job as the interior orientation changed significantly between testfield calibration and use in the field. We attribute this to the fact that the lens was retracted then the camera was switched off. Fairly stable camera geometry in a compact size camera with lens retracting system was accomplished for Sigma DP1 and DP2 cameras. While the pixel count of the cameras was less than for the Ricoh, the pixel pitch in the Sigma cameras was much larger. Hence, the same mechanical movement would have less per pixel effect for the Sigma cameras than for the Ricoh camera. A large pixel pitch may therefore compensate for some camera instability explaining why cameras with large sensors and larger pixel pitch typically yield better accuracy in object space. Both Sigma cameras weigh approximately 0.250 kg and may even be suitable for use with ultralight aerial vehicles (UAV) which have payload restriction of 0.200 to 0.300 kg. A set of other cameras that were available were also tested on a calibration field and on location showing once again that it is difficult to reason geometric stability from camera specifications.
Image acquisition with geometrically stable cameras was fairly straight forward to cover the area of interest with stereo pairs for analysis. We limited our tests to setups with three to five images to minimize the amount of post processing. The laser dot of the laser distance meter was not visible for distances farther than 5-7 m with the naked eye which also limited the maximum stereo area that may be covered with this technique. Extrapolating the setup

to fairly large areas showed no significant decrease in accuracy accomplished in object space. Working with a Sigma SD14 SLR camera on a 6 x 18 x 20 m3 volume the maximum length measurement error ranged between 20 and 30 mm depending on image setup and analysis. For smaller outcrops even the compact cameras yielded maximum length measurement errors in the mm range which was considered sufficient for measurements in the earth sciences. In many cases the resolution per pixel was the limiting factor of image analysis rather than accuracy. A field manual was developed guiding novice users and students to this technique. The technique does not simplify ease of use for precision; therefore successful users of the presented method easily grow into more advanced photogrammetric methods for high precision applications.

Originally camera calibration was not part of the methodology for the novice operators. Recent introduction of Camera Calibrator which is a low cost, well automated software for camera calibration, allowed beginners to calibrate their camera within a couple minutes. The complete set of calibration parameters can be applied in ERDAS LPS software easing the workflow. Image orientation was performed in LPS 9.2 software which was also used for further image analysis.