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A SIMULATION STUDY FOR THE GEOMETRIC ACCURACY TESTING OF AIRBORNE LINEAR ARRAY CCD CAMERAS

S KOCAMAN[1], A GRUEN[1]

(1) Institute of Geodesy and Photogrammetry, ETH Zurich, Zurich, Switzerland.

Since their first introduction, linear array CCD cameras play an important role in the airborne optical digital sensors market, together with matrix array CCD sensors. The methods and algorithms to process airborne linear array imagery opened a wide research area to the scientists and software developers due to its fairly new geometry and the integrated use of data from auxiliary sensors. GPS and IMU systems are used during the flight in order to get high precise position and attitude data, which forms the image trajectory as an essential input for further photogrammetric processing. To make efficient use of airborne linear array sensors, new processing methods needed to be developed and the existing ones re-designed. Algorithms and software for a complete photogrammetric processing chain for TLS imagery have been developed at our Institute at ETH Zurich since the year 2000. For the triangulation of TLS imagery, a modified bundle adjustment algorithm with the possibility of use of three different trajectory models was developed by Gruen and Zhang (2002): (a) Direct georeferencing with stochastic exterior orientations (DGR), (b) Piecewise Polynomials with kinematic model up to second order and stochastic first and second order constraints (PPM) and (c) Lagrange Polynomials with variable orientation fixes (LIM). The modelling aim is to abate the systematic errors and the noise of the given trajectory data. Each model has different characteristics, such as the functional models, number of unknowns, stochastical constraints, etc., and show different behaviours under different network conditions. For example, the DGR model produces 9 unknown parameters for exterior orientation of each strip, whereas the number of unknowns depends on the given number of orientation fixes in case of the LIM. In comparison to the DGR model, the LIM and the PPM have much more complex functional models, and require higher attention of the user before performing a bundle adjustment and for post-analysis.

Later on, self-calibration capability is added to the bundle adjustment algorithm and integrated to the three trajectory models. In addition to the Brown's lens distortion model, our self-calibration algorithm includes line-based additional parameters for a better systematic error modelling.

One of the major aims of this study is to investigate the TLS sensor geometry and its accuracy potential. For this purpose, several TLS data are tested under various network conditions. The test networks vary with the numbers and distributions of the ground control points, tie/pass points, and also the numbers and distributions of the TLS images. The modeling capabilities of the developed trajectory models and their efficient utilization under these network circumstances are to be investigated. In addition, the determinability of additional parameters for self-calibration is to be investigated.

To have a better control on the systematic and random errors behaviour of the data, we have created a flight dataset with a simulated TLS camera. The dataset contains trajectory data for 3 parallel and 2 cross strips. The GCPs and tie/pass points are distributed densely. The simulated camera includes three parallel line sensors, in three different viewing directions (forward, nadir, and backward directions). The terrain is assumed to be flat and the objectspace coordinates of the GCPs are assumed to be error-free.

Similar network and accuracy investigations are performed using real data acquired with the STARIMAGER sensor of the former Starlabo Corporation, Tokyo, and ADS40 sensor of Leica Geosystems, Heerbrugg, over two different testfields. The STARIMAGER dataset acquired over the Yoriichio testfield suffers from insufficient image quality, bad definition of signalized points and problems in GPS/INS processing. The test results should be interpreted accordingly. The ADS40 data acquired over the Vaihingen/Enz testfield has very high apriori precision of the given trajectory data. However, ADS40 tests do not meet the complete test scheme, due to the limitations of the provided dataset. Characteristics of our two trajectory models, the DGR and the LIM, are demonstrated with several GCP distributions; and the determinability of additional parameters is another main finding from this dataset.

The theoretical precision parameters are evaluated using the covariance matrix elements. The empirical accuracy results are evaluated using independent checkpoints. The test results are presented in this paper.