ASPRS GUIDELINES FOR GEOMETRIC CALIBRATION OF OPTICAL AERIAL CAMERA SYSTEMS

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Abstract

Primary concerns of the JACIE team (NASA, NIMA, USGS) are the characterizations of geo-positional, spatial and radiometric qualities of image data. This paper addresses the geometrical calibration of geo-spatial and spatial image data collection systems employed by the photogrammetric community. The history, technical basis, application, and future of the ASPRS guidelines for camera calibration will be discussed.

BACKGROUND

The announcement by USGS in March of 2011 indicating they would no longer offer calibration services for airborne optical sensors, both film-based and digital cameras, ignited a strong interest in establishing suitable alternative sources of camera calibration. At the March meeting of the ASPRS in Milwaukee, the Camera Calibration Committee was established to address future camera calibration issues. (It is noted that USGS subsequently decided to continue laboratory calibrations of film-based cameras as funds permit.)

Working with a committee of more than fifty people that expressed interest, the Calibration Committee developed a suitable draft expressing specifications for the metric calibration of both the film-based and digital airborne optical camera systems. The specifications included guidelines for establishment of suitable test and calibration fields. The resulting document, published in the July 2013 issue of Photogrammetric Engineering and Remote Sensing, titled “Guidelines for the In Situ Geometric Calibration of the Aerial Camera System” (ASPRS 2013), was accepted by the ASPRS board of directors at their October, 2013 meeting in San Antonio.

IS CALIBRATION NECESSARY?

To answer the question one must first ask, what are the geospatial accuracy requirements for the operational airborne photogrammetric system? Well-established accuracy requirements are usually associated with specific tasks such as large scale topographic mapping for transportation planning and design. For design of modern highways, the elevation accuracy requirement may be the controlling factor in specifying the photogrammetric accuracy and may be as small as a few centimeters. To the extent that the photogrammetric system can achieve such elevation accuracies will be a factor in design of field control surveys necessary.

To achieve such high levels of accuracy it is prudent to not only calibrate the photogrammetric system under operational circumstances ("*in situ*"), but to verify that the system is performing in accord required level of accuracy. The ASPRS guidelines describe a means for calibration of the system.

Little has been published regarding accuracy verification of a well calibrated system. One means for this is to withhold constraints in a bundle block adjustment on well-defined control and evaluate comparisons between photogrammetric results and independent surveys of higher accuracy. This is a typical approach to accuracy assessment.

A more fundamental approach to spatial accuracy is to compare the photogrammetrically resected coordinates to the corresponding exposure station coordinates provided by GPS. If the calibration range design described in the ASPRS calibration guidelines is used, an individual photo will contain approximately 25 well-defined, targeted and controlled images. A series of photos, corrected for calibration results may be used to compute resections, and results compared to GPS values. This approach forces any residual calibration errors to the forefront and permits assessment of their sources.

An example of such accuracy assessment is provided in Table 1. for an open-ported aircraft at 1260 meters (Merchant, 2012). For further examples of spatial accuracy comparisons between *in situ* calibrations and laboratory calibrations, refer to (Merchant, 2004).

Note that the overriding systematic error is in elevation when comparing a laboratory calibration by resection to the corresponding GPS position. The influence of temperature on flight height by resection was reported for a Nikon DX2 camera flying at 2000 meters above ground level (Merchant, 2012). The influence is essentially linear comparing focal length to temperature. If a closed-ported, pressurized aircraft system is used to control temperature, the distortion produced by pressure on the window will cause significant distortion. This is evidenced in Table 2. From both examples, the calibrations of both laboratory and airborne result in small bias and rmse errors for the X and Y components. The elevation components approach one part in two thousand of the flight height. Considerable ground control will be required to correct elevation distortions of this magnitude, particularly over terrain of irregular elevation.

If a closed-ported, pressurized aircraft system is used to control the temperature, the distortion produced by pressure on the window will be significant. This is evidenced in Table 2. In both examples (Table 1 and Table 2.), the calibrations of laboratory and airborne (*in situ*) result in small bias and rmse errors for the X and Y components. The elevation components approach a bias error of one part in 2,000 of the flight height for the laboratory calibration. For the airborne calibration, the elevation bias approximates one part in 100,000 of the flight height. Considerable ground control will be required when using laboratory calibrations to correct elevation distortions, particularly over terrain of irregular elevation.

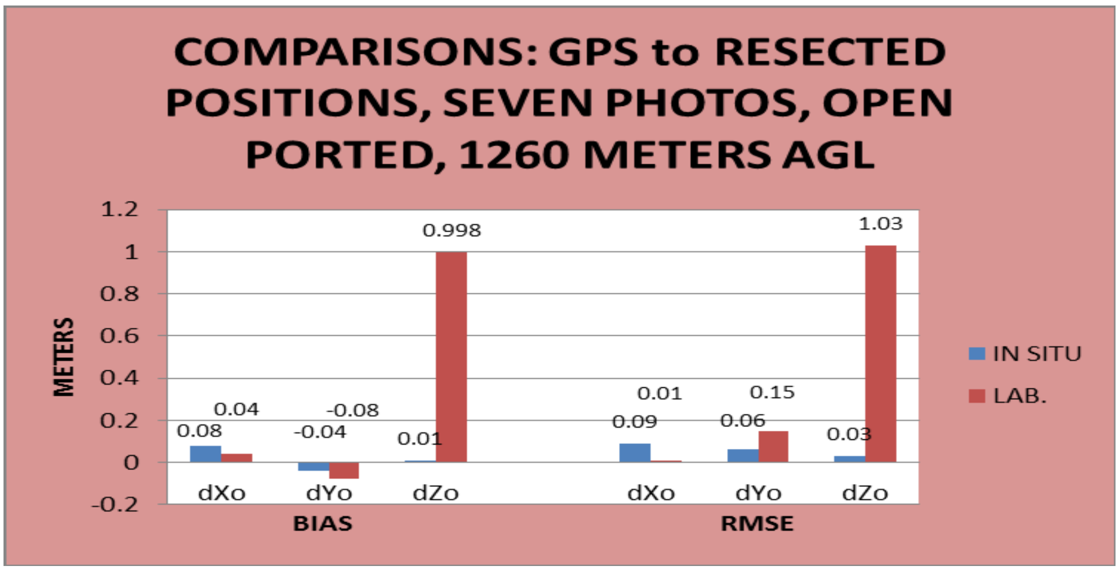

Table 1. Exposure Station Differences; Resection Compared to GPS, Open Port

Table 2. Exposure Station Differences; Resection Compared to GPS, Closed Port

THE PLUMWOOD TEST AND CALIBRATION RANGE

The Plumwood Range is located in central Ohio north of the village of Plumwood and is centered at (**N40 03 37.9, W83 24 27.7**). This range served to provide the sample camera system calibration data for the ASPRS Guidelines. The range was constructed through cooperation between Midwestern Aerial Photography and Topo Photo Inc.

FIGURE 1. Distribution of Controlled Targets on a Cross-Road Range

Figure 1. shows a typical crossroad range design as described in the guidelines. Use of a cross-road as the location of the range provides wide flexibility in site selection. Rather than requiring great elevation differences within the range, or special orientation with respect to north, this design requires only that targets nominally be laid out as a cross. To provide target images uniformly across the photo format, the aircraft is flown over the range in a small series of bearings with respect to the roads.

Experience has shown that for a total number of twenty five targets, painted on good quality asphalt for instance, and surveyed by GPS, that a range can be established by a two man survey party in approximately one week. This includes site selection, target placement, survey and reporting. However, final network adjustment must wait several weeks for final orbit data to be available. For the Plumwood Range, the relative accuracy along each axis including elevation is less than one centimeter RMSE.

CONCLUSION

The guidelines for calibration of the airborne metric camera system (ASPRS), approved by the Board of Directors are directly in line and in support of the objectives of the JACIE team (NASA, NIMA, USGS), (SSC/FED-02-001-06).

It is anticipated that subsequent work will be conducted by ASPRS through committee activity to improve and broaden application to IMU and image quality.

The current ASPRS Guidelines use the standard SMAC model employed by the USGS for their laboratory calibrations. In addition, correction for refraction uses the Saastamoinen (Saastamoinen,1972) model and earth curvature is treated by use of three-dimensional Cartesian coordinates assigned to the range targets. Finally, commercial software for conducting the aerial triangulation may include the treatment of elements of camera interior orientation as unconstrained parameters of the adjustment computation.

The primary differences between the ASPRS Guidelines and other approaches

are:

- More accurate geospatial solutions due to high density of targeted control.
- Less restrictive specifications in calibration field design
- Less expensive for data providers (operators) and without need to disassemble the camera system from the aircraft when compared to laboratory approaches

Recognition is given to the members of the ASPRS Calibration Committee for their contributions to the formulation and acceptance of the Guidelines. Their meaningful and constructive responses, on two week cycle intervals, allowed significant progress be made toward a near final draft within a six month period.

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