KEYSTONE AERIAL SURVEYS, INC.

AN ACCURACY ANALYSIS OF LARGE RESOLUTION IMAGES CAPTURED WITH THE NIKON D810 DIGITAL CAMERA SYSTEM

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ABSTRACT

The use of commercially available non-metric camera (e.g., Canon, Nikon) for photogrammetric operations is becoming very popular. There are several reasons for their use, such as lighter payload, low cost of sensor, smaller size for limited on-board space as in the case of UAVs as the data acquisition platform, quick turnaround projects, ease of replacement, etc. All these attributes represent advantages as compared with the use of digital high resolution metric image sensors (Hexagon DMCs, Microsoft Vexcel UltraCam systems, etc.). Nevertheless, in order to achieve results approaching those obtained with the use of the metric systems, it is imperative to take into account all the systematic errors the mentioned non-metric image sensors have; to model them and to eliminate (or minimize) their impact on the acquired images. This paper includes a review of the functional and stochastical models to be used in connection with the utilization of the non-metric image sensors. Attention will be given to the sensor inner calibration parameters i.e., calibrated focal length, principal point, symmetric – asymmetric – tangential lens distortions patterns and others biases that can strongly distort the acquired images. With this purpose the photogrammetric test field area “Franklin Mills Mall” was flown with the Nikon D810 Digital Camera with 50 mm focal length for camera calibration. The field was covered with multiple flight heights resulting in images at 15 and 30 cm GSD respectively. Two perpendicular photogrammetric flight strips with high end lap and side lap were flown. The test field area possesses some 25 targeted control and check points that have been measured with an accuracy of 2 cm or better. Automatic aerial triangulation using the above described imagery was conducted using PIX4Dmapper, a software package created specifically for images acquired from a UAV or terrestrially. The image observation results were exported (ASCII) and the corresponding Bundle Block Adjustments were conducted using the Leibnitz University of Hannover program system BLUH that is able to perform self-calibration through Additional Parameters (twelve standard plus different distortion patterns of mid-size format digital non-metric cameras). Varying numbers and distribution of Ground Control Points (GCPs) and Check Points (ChkPts) were used in the investigation. The results are presented herein.

CAMERA USED

During this investigation, Keystone Aerial Surveys, Inc. flew the Nikon sensor in a configuration to collect nadir imagery from altitudes of approximately 5000 feet (1525 m) for the 15 cm GSD imagery and 9000 feet (2740 m) for the 30 cm GSD. The system platform is not as significant as the camera itself. It is a camera that is relatively inexpensive, can be mounted on any aircraft and most unmanned aerial vehicles, and can easily be configured to automatically capture imagery. The Nikon D810 used has the specifications of: 36 Megapixels, a pixel size of 4.88 microns, 7360 x 4912 (cross x long) pixels, sensor size of 35.9 x 24 (mm), Dimensions (w x h x l) 146 x 123 x 82 (mm). A Nikkor AF lens with a Nominal Focal Length of 50 mm was used.

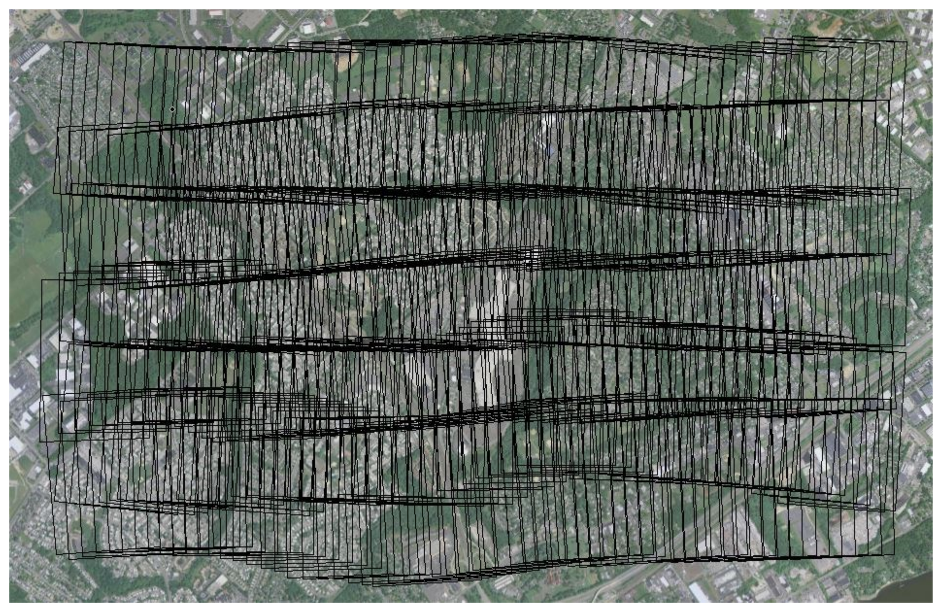
THE FRANKLIN MILLS MALL TEST FIELD AREA

Located near the Northeast Philadelphia airport, the large Franklin Mills Mall maintains a huge parking lot with plenty of parking stripes that can be used as targets at intersecting lines. It is surrounded by neighborhoods of family houses with streets having plenty of painted traffic lines with intersections and other features easily used as target control points. The total area of the test field is approximately 7 sq. miles and with a difference in height of about 75 feet, it incorporates 25 targeted ground control points (GCP) that were field surveyed with an accuracy of 2 cm or better. The area has plenty of details and is suitable for many sensor calibration purposes. Figure 4 shows a typical detail of a GCP and Figure 3 shows the distribution of such points.

Overview of the Test Field Area and GCP

Imagery Mosaic Overview

Typical detail of ground control point



East/West flight image footprints

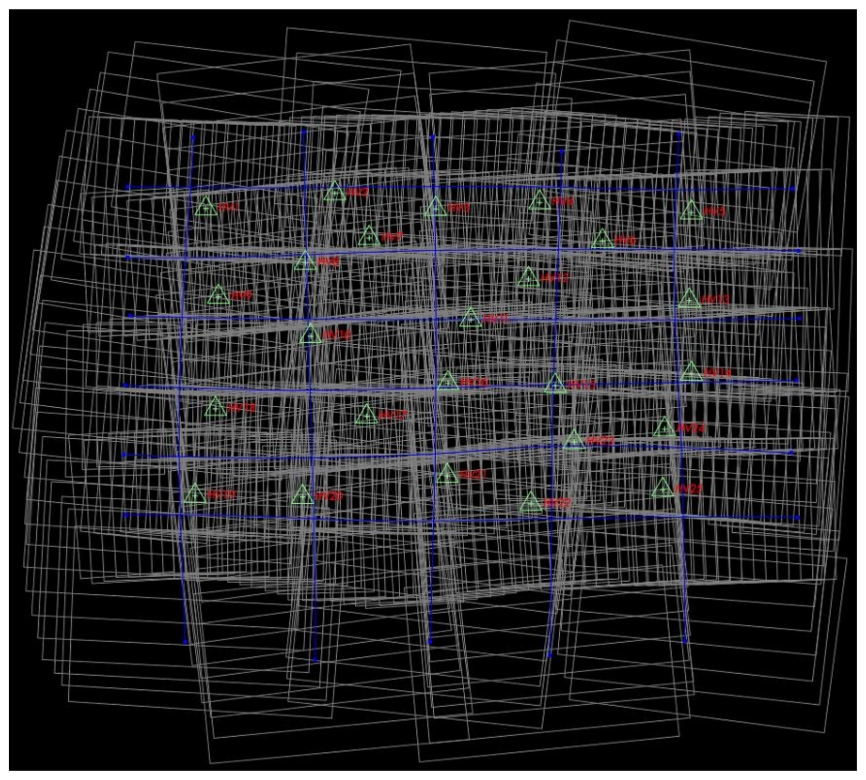
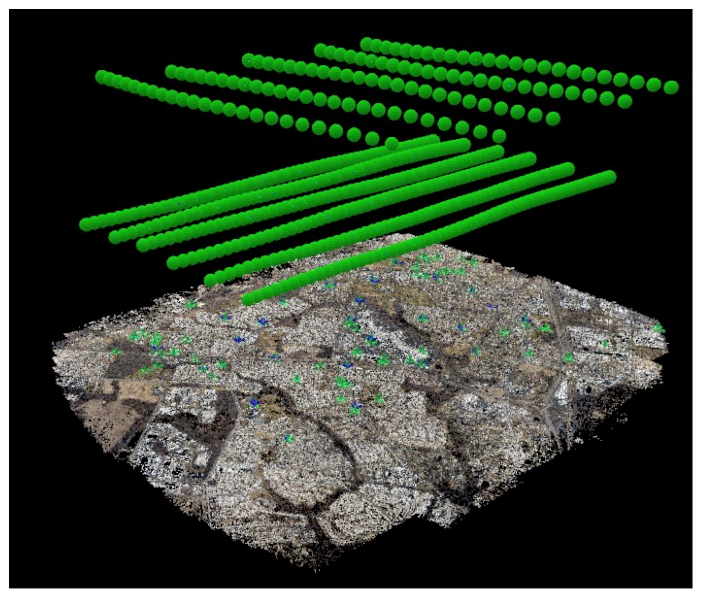
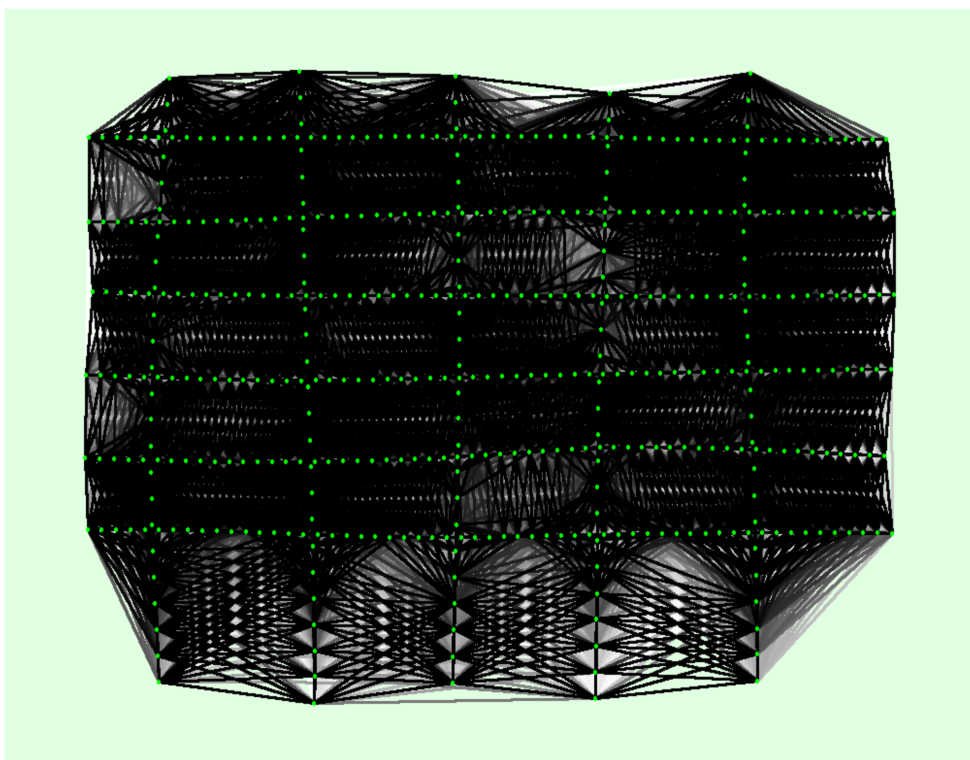


Image footprints of both high and low flights with Ground Control Displayed

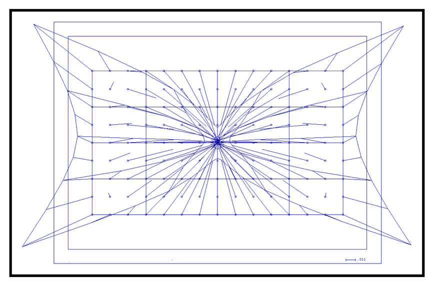


Projection centers with match points generated by Pix4DMapper

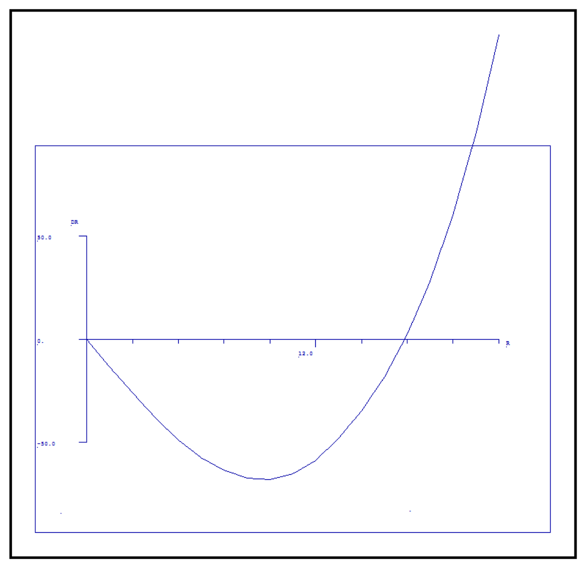


Density of intersected homologous intersected rays

Least Squares Bundle Block Adjustment Summary															
No self-calibration				12 Standard Add. Param				12 St. + Mid Format CCD Cam.				1 - 9, 12, 27-28, 81-88			
σ_o	RMX	RMY	RMZ	σ_o	RMX	RMY	RMZ	σ_o	RMX	RMY	RMZ	σ_o	RMX	RMY	RMZ
14.0	0.53	0.39	2.43	3.3	0.12	0.19	0.68	2.89	0.12	0.19	0.30	2.7	0.08	0.09	0.25



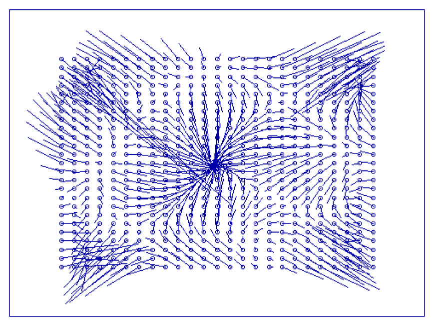
Systematic image errors of the camera computed by additional parameters



Radial Distortion Curve of the camera lens computed out of the self-calibration

The table above summarize the results of the LS BBA adjustment in terms of Overall Standard Deviation (µm) and Root Mean Square Discrepancies (m) on Ground Control Points for the following cases:

LS BBA with no self-calibration
LS BBA with self-calibration using 12 standard additional parameters
LS BBA with 12 standard additional parameters plus add. Param. for typical Mid Format CCD Cameras
LS BBA with additional Parameters 1 to 9, 12, 27 to 28 and add. Param. for typical Mid Format CCD Cameras



Systematic image residuals/correction grid resulting from self-calibration with add. Param. 1 to 9, 12, 27 to 28 and 81 to 88.

Another adjustment was carried out with BLUH using additional parameters 13, 14 and 15 (parameter 14 is associated with correction to the nominal focal length to obtain a calibrated focal length, whereas parameters 14 and 15 are associated with calibrated principal point of the camera. The results were as follows:

X-COORDINATES SHIFTED	LEFT= -0.274 mm	RIGHT= 0.274
Y-COORDINATES SHIFTED	LEFT= -0.119	RIGHT= 0.119 mm
CHANGE OF FOCAL LENGTH =	0.089 mm	

Direct Intersection				12 St. + Mid Format CCD Cam			
σ_o	RMX	RMY	RMZ	σ_o	RMX	RMY	RMZ
5.34 µm	0.25 m	0.28 m	1.88 m	2.75 µm	0.10 m	0.15 m	0.38 m

CONCLUSIONS

- Despite the flight being conducted at GSDs not intended for this system and using JPEG imagery, the results were excellent: sub pixel accuracy for horizontal and 1 or 2 pixel (depending on GSD) for the vertical.
- Image enhancement techniques performed on the JPEG imagery increased the matching performance significantly but added more pixel shift to the shift created by the lens distortion.
- For highest possible accuracy with this lens configuration, it is best to capture with lower flying heights and RAW imagery formats. This will minimize any radiometry based matching failures and eliminate some increased image distortion.
- As expected, the digital camera NikonD810 has very large radial distortion that it is also combined with tangential and asymmetric distortion (See above used additional parameters).
- To achieve better reliability when calculating the PPA, a flight with all lines flown in both forward and reverse directions should completed. An area with greater GCP height variation should also be explored as this will allow for focal length calculation to be performed.
- It has been proven that if used properly it is possible to achieve very acceptable results with off the shelf cameras.
- Due to the large radial (and other) lens distortion, the images of the camera must be corrected using the additional parameters to eliminate (or minimize) the effects of the systematic effects on the images themselves. This is the case of using the imagery acquired by this type of camera for purposes of texture in 3D models

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