ESTABLISHING NATIONAL DIGITAL PHOTOGRAMMETRIC AIRBORNE CAMERA CALIBRATION FIELD IN TAIWAN

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ABSTRACT:
The first digital photogrammetric airborne camera was introduced in 2004 to Taiwan. Today numerous mapping projects in Taiwan rely on images gathered from ADS, DMC or UltraCAM. As the sole central government agency responsible for surveying and mapping, National Land Surveying and Mapping Center began to study the calibration of digital photogrammetric airborne cameras in 2011 in compliance with the National Land Surveying Law. A calibration field was set up and tests have been carried out to establish a proper test procedure. UltraCAM and DMC cameras were used for the tests. Geometric characteristics of them were analyzed. Results show that the calibration field and the proposed calibration procedure fulfill the quality estimation purposes.

KEY WORDS: Camera calibration, UltraCAM, DMC, UAS

1. BACKGROUND

The first digital photogrammetric airborne camera was introduced to Taiwan in 2004. Today different kinds of photogrammetric cameras including ADS-40, DMC-I, DMC-II, UltraCAM-D, UltraCAM-Xp, UltraCAM-Xp w/a are in operation for topographic mapping projects all around Taiwan.

In USA, the USGS established OSL in 1973. With the development of digital camera, the USGS drew up a digital camera quality assurance project in 2000. Drafted documents include the “2008/2009 digital aerial imagery calibration/product validation range requirements”, “DIQAP implementation plan” (Stensaas, et al., 2008).

In Europe, the EuroSDR started digital aerial camera system calibration and verification in 2003. The tests of DMC, UltracamD, ADS40 were performed. Also, the European digital airborne camera certification-EruoDAC [2] was proposed in 2007.

As to Asia, in 2002 the committee of test field was formed and on Oct. the field was set up in Japan. As for China, the tests of ADS40, DMC and ALS50 were implemented in 2009

In Taiwan, the National Land Surveying Law demands that all surveying instruments used for land survey have to be calibrated periodically. The National Land Surveying and Mapping Center (NLSC), as the sole central government agency for surveying and mapping, established a survey instrument calibration laboratory which has been accredited by the Taiwan accredited foundation (TAF), the local organization a member of the global organization ILAC-MRA, in 2010. Today all the ground surveying instruments including EDM, GPS , theodolite and levelling instruments can be calibrated by this lab. Considering the importance of airborne mapping equipments, the NLSC began to study the calibration of digital photogrammetric airborne cameras in 2011 (Wang et al., 2013).

2. CALIBRATION DESIGN AND PROCEDURE

The selection of a proper site for the calibration range follows basically the recommendation of the USGS range requirements. The 2m*1.75m range site, with 180m terrain height variation, with permanent GNSS station and known national control points nearby, is located in the centre of Taiwan.

Inside the range, fixed signalized 1m by 1m targets, suitable for 5 to 25 cm Ground sampling distance (GSD), were laid out for geometric calibration. Their coordinates are obtained periodically by static GPS. The accuracy is better than 2cm in horizontal and 5cm in vertical.

Portable Modified Siemens Star as recommended by USGS is used for spatial resolution calibration.

For studying the feasibility of radiometric calibration portable grayscale with 8 reflectance steps similar as the calibration target used in black to white Sjokulla test field.

In order to reach a near-Lambertion reflectance, sandpaper with fabric base painted with continuously changing mix-proportion of black and white paints is used as target.

The first subject is the geometric calibration of the camera. This is conducted with practical flying mission.

In order to get high reliability flight lines with, 80% forward-lap, 60% side-lap and crossed flight lines in 4 directions were designed. This flight line arrangement also ensures that the signalized control points can be presented over the entire image area. Sixteen ground signalized targets located in the corner and along the sides were used as control points. The rest signalized targets serve as check points.

The second subject is the spatial resolution. This is calibrated from the concepts of the modulation transfer function (MTF) and point spread function (PSF) with the procedure similar to what the Finnish Sjoekulla test field has used (Hognkavarra, et al., 2008). The marginal black and white sectors of photographed modified Siemens Star image were chosen to be 100% modulated reference value. At constant interval, the sector were sectioned and compared to 100% modified reference value. The PSF is basically related to MTF via the function below (Li, 2000).

$$\text{scale} \cdot \text{MTF}(k) = e^{-2\pi^2 \sigma_{PSF}^2 k^2}$$

A step edge including black and white block as marked in the red box shown in Figure 2 was used to calculate PSF.

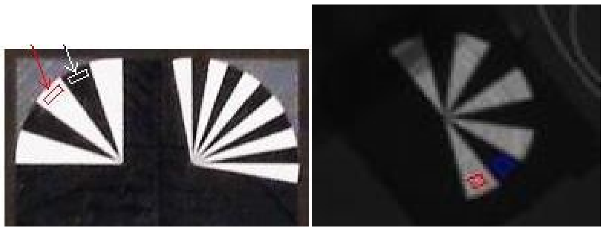

Figure 1 100% modified reference value (left: target used in GSD 5 to 25cm , right: target used in GSD 10cm)

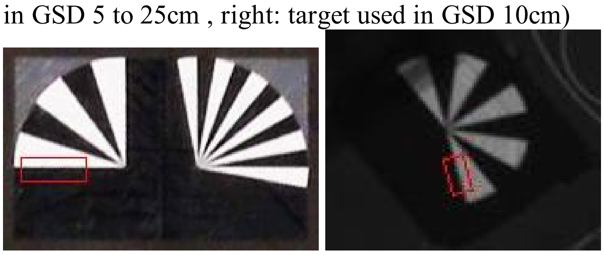

Figure 2 step edge (left: target used in GSD 5 to 25cm , right: target used in GSD 10cm)

The third subject is radiometric calibration. Both the radiometric linearity and spectral reflectivity were examined. Spectrum of the white board, used as standard, and tray scale target were measured by spectrometer.

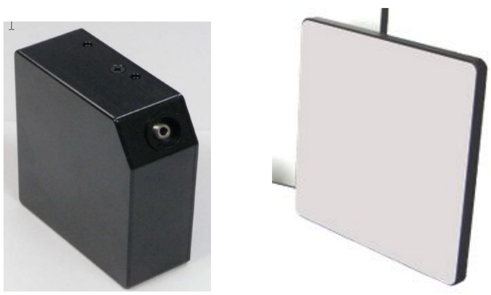

Figure 3 Field Spectrometer (left: spectrometer, right: Spectralon board)

3. CALIBRATION RESULTS

The research focused mainly in large format photometric camera, the UltraCamXp and DMC I, but the camera mounted in NLSC UAS was also included. Results show that both geometric and spatial resolution calibration procedures were feasible, as to radiometric calibration further study is still pending.

From the four-fold trips, the center one was selected to examine the residual errors of all check points. Root mean squared error served as an index to the geometric quality of the calibrated camera. Since four-fold block was flown for each camera the ties between images are very strong providing a very sound base for applying the method proposed by Masson d'Autume (1972) to estimate image distortion in detail.

UltraCamXp: Flight tests of GSD 5 and 20cm were conducted. Root mean squared errors on 32 check points is about 1/4 of GSD in horizontal and 1/2 in height for the 20cm GSD block. From the residuals of all tie points obtained after the block triangulation image distortion pattern was estimated according to the method proposed by Masson d'Autume. Figure 4 shows the results.

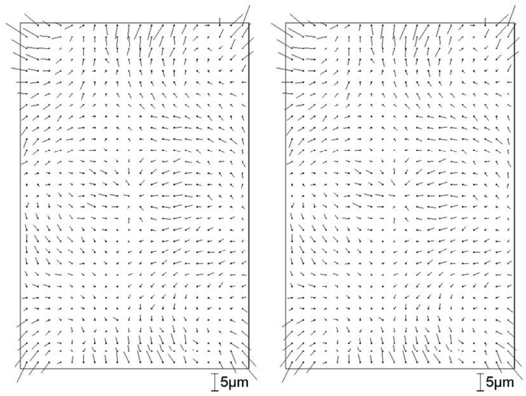

Figure 4 Distortion pattern of the UltraCam (left:GSD5cm, right:GSD20cm)

DMC: Flight test of GSD 8 cm was conducted. Root mean squared errors on 32 check points is 1/8 of GSD in horizontal and 1/2 of GSD in height. Again the distortion pattern was estimated and shown in Figure 5.

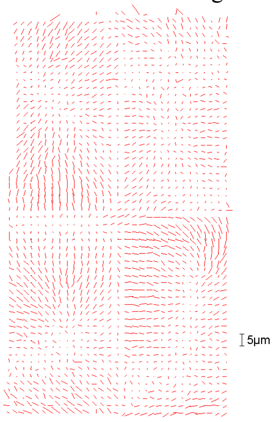

Figure 5 Distortion pattern of the DMC

NLSC UAS: The NLSC built an UAS with fixed-wing aircraft and Canon 5D Mark II mounted. Test of GSD 15 cm was conducted. The original image has very large distortion (Fig.5 left, scale bar 30μm). After some additional parameters provided by ORIMA aerial triangulation software were introduced, the image quality is by far improved (Fig.6 right, scale bar only 5μm).

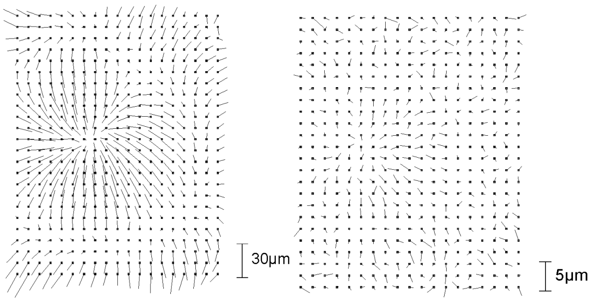

Figure 6 Distortion (left: original, right: parameter added)

The MTF and PSF were measured and computed.

MTF: The surface of the tarp target used in UltraCamXp test was not close enough to a Lambertian diffuse surface. In comparison the sandpaper used in the DMC test presents a much better diffuse property. Figure 7 shows the measured modulation values at different frequencies for UltraCam (left) and DMC (right).

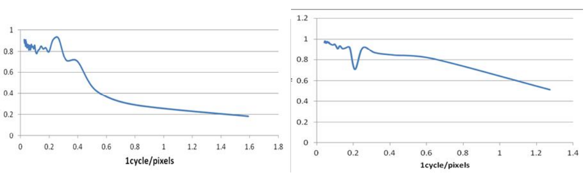

Figure 7 MTF curve (left: UltraCamXp , right: DMC I)

PSF: From the edge image gradient values across the edge were measured and PSF could be estimated following the method proposed by Li (2000) The PSF value of UltraCamXp and DMC I was 0.93pixel and 0.53pixel respectively.

In the 2011 53rd Photogrammetric Week, a paper entitled "geometry perfect – radiometry unknown?" indicated that radiometric calibration for photogrammetric cameras is still a topic in research (Craymer, 2011). The dilemma is the purpose of the calibration.

Radiometric Linearity: Figure 8 shows the measured intensity on the 8-step greyscale targets versus the true target reflectance for UltraCam (left) and DMC (right).

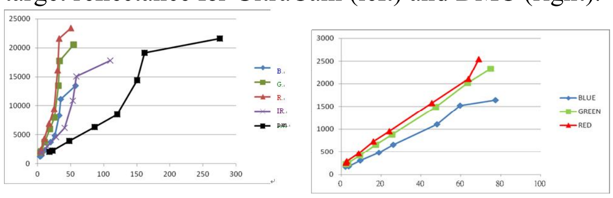

Figure 8 Linearity pattern
(left: UltraCamXp , right: DMC I)

4. CONCLUDING REMARKS

The calibration range set up by NLSC is experimentally proven to be suitable for calibration of the geometric accuracy and geometric resolution of digital aerial cameras use for photogrammetric applications. The range will be operated and maintained by NLSC routinely in the future and serves as a national calibration facility.

5. FUTURE STRATEGIES

It remains a question as to the aim of radiometric calibration of photogrammetric cameras. The color images from photogrammetric cameras are mostly used to produce orthophoto for human observation not for remote sensing classification. Since human eyes respond to spectral reflectance not linearly it can be expected that a radiometrically correct color image might appear "unnatural" to human eye.

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