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Evaluation of Panchromatic IKONOS Data for Mapping.

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Abstract

The results of assessment of the planimetric accuracy of 1- meter resolution panchromatic IKONOS data comparing to the topographic map in the scale 1:10,000 are presented.

Low precision georeferenced Carterra Geo, 50 m CE90 product of test areas in China was orthorectified in IGiK using ImageStation INTERGRAPH and International Imaging System PRISM VISTA software as well as software elaborated in Chinese Academy of Surveying and Mapping (CASM).

Planimetric accuracy of IKONOS data after adjustment with the use of 5 GCP's (taken from the topomap) was: RMSEx = +/- 1.1 m and RMSEy= +/- 1.4m.
Planimetric accuracy calculated on 18 check points, the X,Y coordinates of which have been also taken from the topomap was: RMSEx = +/- 3.5m and RMSEy= +/- 2.5 m.

Planimetric accuracy of the orthophotomap generated using IKONOS data and calculated transformation parameters was: RMSEx = +/- 3.7 m and RMSEy= +/- 3.6 m. This accuracy is similar to the planimetric accuracy of the topographic map in the scale 1:10 000.

Better accuracy can be achieved by measuring GCP's directly in the field with GPS technique instead of using topomaps. Nevertheless, Carterra Geo product which is of the lowest horizontal precision out of the entire range of IKONOS products and also the cheapest, can be used for updating topomaps as well as for generating up-to-date digital basemap in modern Geographic Information Systems.

1. Satellite systems using push broom scanner.

As a pioneering example, SPOT Image of France launched the first pushbroom system in 1987, taking SPOT PAN images with 10 meters resolution for mapping. The success of SPOT lies in that orbit on altitude 830 km guarantees stable acquisition of data from neighboring orbits in side looking option. SPOT series are successful to satisfy users with excellent geometric and radiometric quality. The data from the high-resolution from IKONOS satellite are expected to be used for urban, agriculture and forestry mapping. The success of IKONOS may be the same asthat of SPOT, since it also uses pushbroom linear array CCD scanning system. The imaging geometry of IKONOS is also similar to German MOMS and to the new airborne High Resolution stereo Camera (HRSC).

In table 1 comparison between SPOT HVR PAN and IKONOS -2 PAN mode is shown.

Table 1. SPOT HRV and IONOS PAN mode

	SPOT	IKONOS
Optical focus length [f]	1082 mm	1000 mm
CCD pixel size	13 μm	
Orbit altitude	826 km	680 km
Side looking angle	± 27°	± 45°
Ground Sample Distance	10 m	0.8 - 1.0 m

In case of IKONOS, the difficulty is frequently changing the looking angle of collection of 11 x 11 km ground coverages. It is hard work to collect imagery data with acceptable time and geometry balance. Moreover, it seems even worse in urban area where IKONOS imagery has no competitive priority to aerial photography.

Two kinds of computing models have been developed in CASM for orthographic rectification of IKONOS imagery supplied at lowest cost.

The test areas were selected in South and South-East parts of China. In this paper only the result from one test area is presented.

2. The geometry solution of pushbroom scanner system.

Starting with coordinates of control points in spatial rectangular reference, with formula (1) the coordinates in instantaneous spatial reference are obtained.

$$\dot{X}_k^c = \overline{X}_k^c - \left(\dot{X}_{s_o} + A'(t_i - t_o) \right)$$

$$\dot{Y}_k^c = \overline{K}_k^c - \left(\dot{Y}_{s_o} + B'(t_i - t_o) \right) \qquad (1)$$

$$\dot{Z}_k^c = \overline{Z}_k^c - \left(\dot{Z}_{s_o} + C'(t_i - t_o) \right)$$

where:

$\dot{X}_k^c, \dot{Y}_k^c, \dot{Z}_k^c$ - coordinates of ground control points (GCP's) in instantaneous spatial rectangular

reference system,

$\overline{X}_k^c, \overline{Y}_k^c, \overline{Z}_k^c$ - coordinates of GCP's in spatial rectangular reference system,

$\dot{X}_{s_o}^c, \dot{Y}_{s_o}^c, \dot{Z}_{s_o}^c$ - coordinates of exposure center corresponding to frame center.

In general way, a tangent plane based spatial rectangular reference are selected as a spatial rectangular reference in spatial positioning case.

IKONOS carries GPS receivers and star trackers that can provide coordinates X,Y,Z of the position and attitude data. Suppose in model (2), the attitude of satellite platform are recorded as:

$$\dot{\varphi}_i = \dot{\varphi}_0 + D'(t_i - t_o)$$

$$\dot{\omega}_i = \dot{\omega}_0 + E'(t_i - t_o) \qquad (2)$$

$$\dot{\kappa}_t = \dot{\kappa}_0 + F'(t_t - t_0)$$

In the annotation record of satellite image, the variations were recorded for pitch, roll and yaw.

The idea is that transformation for the coordinates of control points in instantaneous spatial rectangular reference system could be carried out onto observational one with $T_\varphi, T_\omega, T_\kappa$ rotations:

$$\begin{bmatrix} \bar{X}_k^c \\ \bar{Y}_k^c \\ \bar{Z}_k^c \end{bmatrix} = T_\varphi T_\omega T_\kappa \begin{bmatrix} \dot{X}_k^c \\ \dot{Y}_k^c \\ \dot{Z}_k^c \end{bmatrix} \qquad (3)$$

where:

$$X_k^c = -f\frac{\bar{X}_k^c}{\bar{Z}_k^c}$$

$$(4)$$

$$Y_k^c = -f\frac{\bar{X}_k^c}{\bar{Z}_k^c}$$

A group of observational equations could be grouped for final solution of push broom system positioning in space:

$$V_{xk} = F_x(l_{xk}, \dot{X}_{s_0}, \dot{Y}_{s_0}, Z_{s_0} \ldots; \varphi_0, \omega_0, \kappa_0 \cdots)$$

$$(5)$$

$$V_{yk} = F_y(l_{yk}, X_{s_0}, Y_{s_0}, Z_{s_0} \ldots; \varphi_0, \omega_0, \kappa_0 \cdots)$$

Formula from (1) to (5) seem to better simulate the space positioning of push broom system, but problem is that correlation exists between orbit parameter $\dot{X}_s, \dot{Y}_s, \dot{Z}_s$ and attitude $\varphi, \omega, \dot{\kappa}$. Therefore, it is proposed that during calculation:

- for rapid and accuracy convergence, recorded parameters are choosen as the independent observation together with the observational equation group,
- it is recommended to select one out of $\varphi, \dot{X}_s$ or $\omega, \dot{Y}_s$ as unknown parameters in observation equation.

  Fortunately, the GPS gives the orbit parameters of IKONOS satellite data. So, it is possible to get accurate direct solution with a forward resection.

  Some authors proposed a simple orthographic polynomial solution:

$$\bar{x} - \delta_h = a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 xy + a_5 y^2$$

$$(6)$$

$$\bar{y} = b_0 + b_1 x + b_2 y + b_3 x^2 + b_4 xy + b_5 y^2$$

$$\delta_h = [h(x + f\,\mathrm{tg}\alpha)/H]\cdot[1 - (x + f\,\mathrm{tg}\alpha)\sin 2\alpha/(2f)] \qquad (7)$$

Formula (6) and (7) have also been tested in CASM and proven suitable for orthographic rectification by using GCP's.

3. Data used.

A CARTERA Geo IKONOS panchromatic image was acquired over the study area in China. The description of the image data of the test area in China is shown bellow.
Product Image ID: 001 Sensor: IKONOS-2; Acquired Nominal GSD:
Cross Scan: 0.84 meters
Along Scan: 0.87 meters
Scan Direction: 0 degrees
Nominal Collection Azimuth: 4.2928 degrees
Nominal Collection Elevation: 75.97294 degrees
Sun Angle Azimuth: 138.4643 degrees
Sun Angle Elevation: 51.55775 degrees
Acquisition Date/Time: 2000-03-26 02:28 Producer: Space Imaging
Project Name: China
Format: GeoTiff
Band: Pan, Bits/Pixel: 11, Number of Bands: 1
Datum: WGS84, Projection: Universal Transverse Mercator, Zone: 51
UL Map X (Easting): 225366.07 meters
UL Map Y (Northing): 3704546.78 meters
Pixel Size X: 1.00 meters, Pixel Size Y: 1.00 meters
Columns: 10924 pixels
Rows: 10972 pixels

4. Results.

Generally IKONOS PAN "raw" data has a good geometric quality. The same is valid for the data used in test region No. 1. After rectification carried out in CASM with on home software, using 15 GCP's taken from topographic map in scale 1:10 000, RMSEx,y =+/- 3.1 meters was achieved.

In other test area, for which data in oblique view was acquired, considerable time was needed for sensor re-stabilization. Test region No. 2 is a bad example of imagery as attitude of satellite was unstable during the acquisition of data.

The results of IKONOS data elaborated in IGiK using different numbers of GCP's and 17 check points are shown in table 2.

Table 2. Accuracy achieved in IGiK.

	RMSE on GCP's		RMSE on check points	
No. of GCP's	RMSEx [m]	RMSEy [m]	RMSEx [m]	RMSEy [m]
10	2.8	1.6	3.3	2.8
6	2.3	1.3	3.0	3.0
5	1.1	1.4	3.5	2.5

The increase of GCP's over 5 does not improve the geometric accuracy. More important than number is the distribution of GCP's. Accurately located and measured GCP's by GPS can improve geometric accuracy of IKONOS "raw" data. Higher precision of position and attitude of image data would also improve the geometric accuracy of IKONOS images.

Planimetric accuracy of IKONOS data after adjustment with the use of 5 GCP's (taken from the topomap) was: RMSEx = +/- 1.1 m and RMSEy=+/- 1.4m.
Planimetric accuracy calculated on 18 check points, of which X,Y coordinates have also been taken from the topomap was: RMSEx=+/-3.5m and RMSEy=+/-2.5 m.

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IKONOS is the first commercial satellite collecting 1- meter resolution imagery, which can be used for mapping in scale 1:10 000 and even in scale 1:5000 and producing digital orthophotomaps with pixel size 1 m. Cost effective orthophotomaps from IKONOS Geo is suitable as digital image base map for local government. For flat region DTM is not needed. DTM with RMSEz=+/- 2 m and grid spacing 30 x 30 m is needed. Minimum viewing angle of IKONOS data is required.

On Fig. 1 an example of hard-copy of elaborated orthophoto using IKONOS Pan "raw" data

and topomap in scale 1:10,000 are shown.

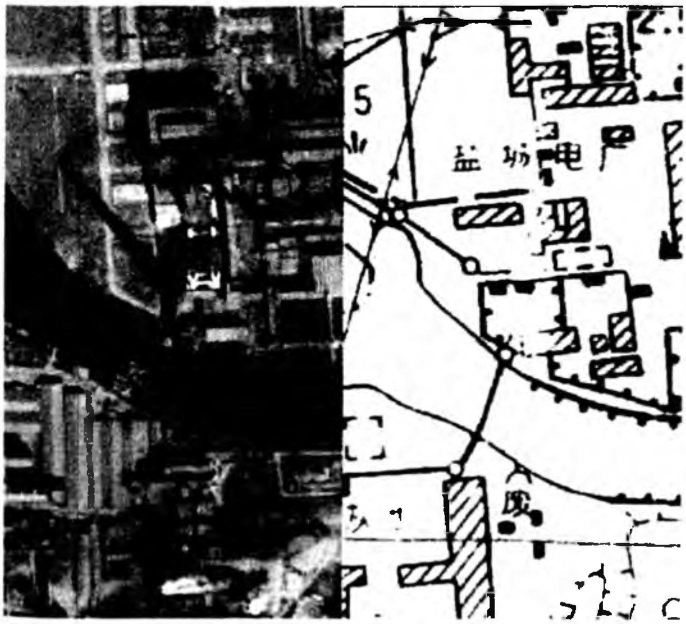

Fig.1. Ortho and topomap in scale 1:10,000.

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