Geometric Potential of Space Images

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0. Abstract

The geometric potential of different types of space images for block adjustment and mapping will be described. Experiences have been made with photos taken by the Large Format Camera, the Metric Camera, SPOT and the KFA-1000 and KATE-200 from Sojuzkarta.

1. Introduction

The use of satellite imagery for mapping in the Western hemisphere started 1983 with the German Spacelab-1 mission, which carried the Metric Camera. A year later the NASA had the Large Format Camera in the space. Both have been experiments with a limited time. In 1986 the French cartographic satellite SPOT was launched. Since 1987 also the images from the Sowjet operational camera missions are available.
Investigations for the cartographic use of the Metric Camera, the Large Format Camera, SPOT and the KFA-1000 and the KATE-200 from Sojuzkarta have been made in the Institute for Photogrammetry and Engineering Surveys of the University of Hannover. But this paper is limited to the geometric potential of these space images.

2. Technical Data of the used Sensors

MC : Metric Camera, F.R.Germany, experiment
LFC : Large Format Camera, USA, experiment
KFA : KFA-1000, USSR, operational
KATE: KATE-200, USSR, operational
SPOT: Line sensor, France, operational

	MC	LFC	KFA	KATE	SPOT
focal length [mm]	305	305	1000	200	2081
film format [mm]	230*230	460*230	300*300	180*180	150*150
flying height [km]	250	225-352	280	280	830
scale number	820000	740000 - 1150000	275000	1400000	400000
covered area [km]	188*188	170*340 - 260*530	80*80	250*250	60*60
ground resolution [m/lp]	16-33	10	5	25	
pixelsize [m]					10-20
reseau	no	yes	no	yes	no
height/base	3.3 : 1	1.6 : 1	8 : 1	2.8 : 1	up to 1 : 1

Table 1: technical data of sensors

special conditions:

MC: no forward motion compensation, disadvantage: low sun angle
film: Kodak 2443 false color infred + Kodak 2405 Double X
LFC: forward motion compensation, reseau projected from back side - reseau moved in relation to fiducial marks
film: Kodak 3414 high definition
KFA: radial symmetric lens distortion up to 600 microns
film: 2 layer film
KATE: set of 3 simultaneously used cameras
film sensitivity: camera 1: 700 - 850 nm
camera 2: 600 - 700 nm
camera 3: 510 - 600 nm
SPOT: line sensor, standard displayed film format: 150 mm * 150 mm with a pixel size of 25 microns for panchromatic mode or 50 microns for multispectral mode
sensitivity for panchromatic mode: 510 - 730 nm
for multispectral mode: 500 - 590 nm, 610 - 680 nm, 790 - 890 nm
nadir angle changeable +/- 27 degrees

3. Data Aquisition for Block Adjustment

Based on the space photographs bundle block adjustments with the Hannover program system BLUH, in the case of SPOT with BINGO have been computed. The computations have been done in tangential plane coordinate systems to the earth ellipsoid because the geometric effect of map projection is not negligible and the earth curvature effect can not be fitted accurate enough just by changing the photo coordinates.
The photo coordinates have been measured computer supported by means of the Hannover program B159 with the Planicomp. The first identification of control points is very time consuming, so the photos are measured two times, the second time based on the result of the first measurement. Only the second data set has been used for the final block adjustment because it is not effected by geometric changes of the instrument caused by the slow first data aquisition.

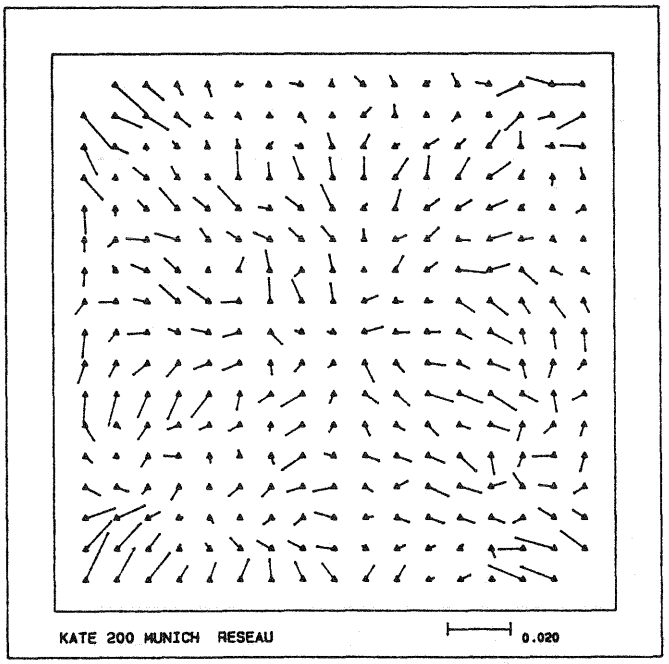
4. Preparation of the Photo Coordinates

Metric Camera: The metric camera has not a reseau, so the preparation of photo coordinates was limited to the radial symmetric lens distortion, which does not exceed 3 microns and the refraction, which is limited to 2 microns.

Large Format Camera: The reseau of the Large Format Camera is projected from the preasure plate to the film. The plate is moved by forward motion compensation, so there is no fixed relation between the reseau grid and the fiducial marks. The calibrated reseau point coordinates have been transformed to the photo coordinates and based on the differences at the neighboured 4 points, corrections by bilinear interpolation have been done. A mean square correction of +/- 3.9 microns has been respected with maximal corrections of 17 microns. The radial symmetric lens distortion has close to the corners values up to 24 microns.

KFA-1000: The format of 300 mm * 300 mm can not be handled in the analytical plotters, so copies with a format of 230 mm * 300 mm have been used. The KFA-1000 has 9 fiducial marks, 4 in the corners, 4 in the centre of each side and 1 in the photo centre. So the transformation to the calibrated fiducial mark coordinates is not a problem. The radial symmetric lens distortion has values up to 600 microns but with a simple dependency of the third power of the radius.

KATE-200: Each of the three simultaneously used cameras has a reseau with a spacing of 1 cm.



The mean square differences at reseau points are between +/- 3 and +/- 4.5 microns with maximal values up to 12 microns. There is a strong correlation between neighboured points, so it is not necessary to measure 17 * 17 reseau points. Without loss of accuracy it is enough to use only each second point (9 * 9 points).

Fig. 1: differences at reseau points of the KATE-200

SPOT: The displayed Spot scenes have a different geometry like usual photos. Just in x-direction there is a perspective geometry. For any different y-coordinate there is a different projection centre. This special geometry is respected in the block adjustment. But the block adjustment presumes an orientation of the satellite to a constant nadir angle. During the 9 seconds of registration one scene, there are high frequent changes of the satellite orientation.

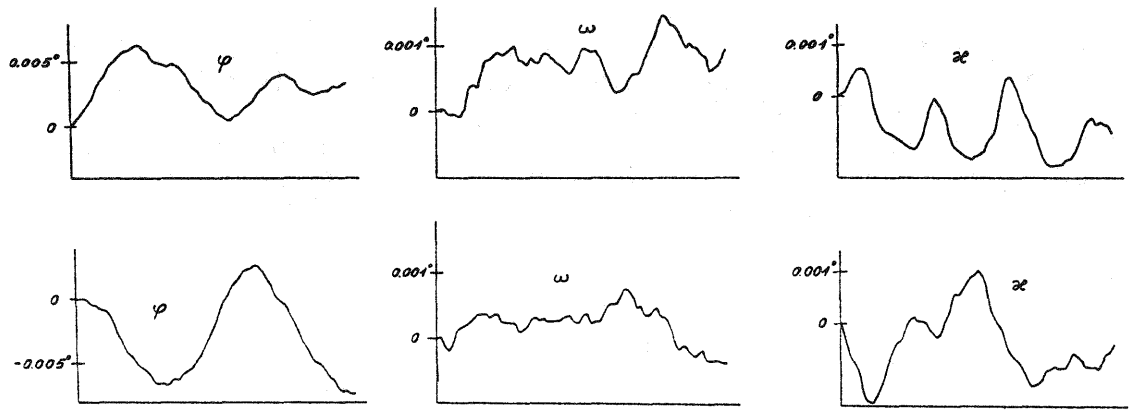


Fig. 2: change of SPOT satellite orientation

The effect of these changes to the SPOT photo coordinates goes up to 45 microns.

5. Block Adjustment

One main problem in handling space photographs are control points. As control points, points from maps 1 : 5000 up to 1 : 62 000 have been used. Such map points are not error free. The accuracy of points from 1 : 5000 is approximately +/- 2m, from 1 : 25 000 and also 1 : 50 000 +/- 12m in X and Y. The height is in relation to the vertical accuracy determined by the space photographs more or less error free. In addition to the map accuracy there are problems in the identification of map positions in the images.

Metric Camera

Several block adjustments have been done with Metric Camera photos.

area	control points	sigma0 [microns]	sx [m]	sy [m]	sz [m]
N. Germany	118	6.2	7.6	7.7	20.2
Alps	65	6.6	16.2	13.6	32.5
east coast USA	59	7.3	12.1	14.3	36.0

Table 2: bundle block adjustments with Metric Camera Photos

The wide range of accuracy is caused by the quality of the control points. In the case of North Germany only control points from maps 1 : 5000 have been used, for the other strips smaller map scales have been used. That means, not the quality of the point determination by Metric Camera photos has been checked, but the existing map accuracy. The same effect has been seen in adjsutments in Sudan and in China, where the control points also have not been accurate enough.

Large Format Camera

At first only 4th generation copies of LFC photos have been available. Later on also 2nd generation copies have been used.

area	generation	control points	sigma0 [microns]	sx [m]	sy [m]	sz [m]
N. Germany	4th	53	12.1	9.9	10.0	14.0
N. Germany	2nd	53	8.2	7.3	9.5	8.5
Alps	4th	217	7.8	4.9	6.6	8.6

Table 3: bundle block adjustments with LFC photos

The remarkable quality difference of the results achieved with 2nd and 4th generation copies are demonstrating the negative influence of the copy process. Similar problems are existing with some MC-copies. Intensive investigations of the copy process with different copy devices have been done. Especially with dodging instruments geometric problems are existing, but also other devices have to be handled carefully and it is not sufficiant to take care just about the photographic quality.
The better results achieved by the LFC photos in relation to the MC photos are caused, in the case of X and Y, by the better resolution of the LFC photos and in the case of the height in addition to this by the double height to base ratio. The effect of the height to base ratio is also demonstrated by the accuracy of points measured in two or three photos.

photos/point	sx	sy	sz	number of points
2	5.3 m	6.7 m	10.8 m	76
3	4.7 m	6.5 m	7.1 m	141

Table 4: LFC Alps effect of number of photos/point to accuracy

KFA-1000

The photos taken with the KFA-1000 are sold by Sojuzkarta. The block adjustments have been done with and without correction of the photos by radial symmetric lens distortion. The results of the adjustments have been more or less the same because it was possible to fit the lens distortion by self calibration with additional parameters.

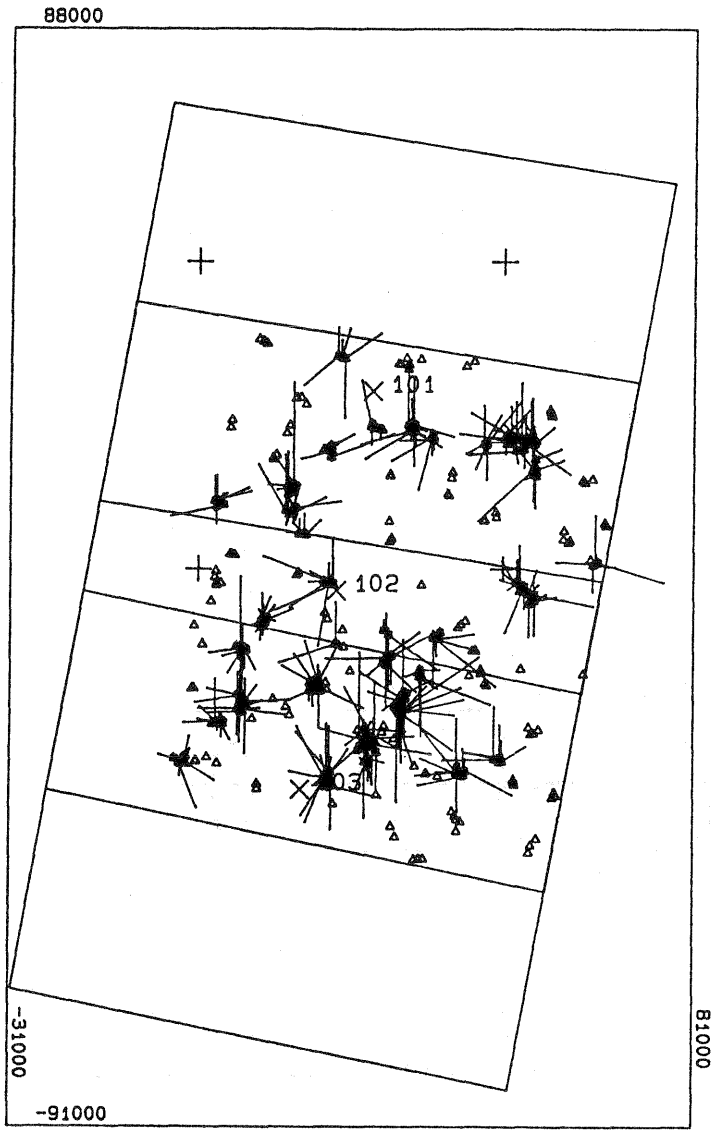
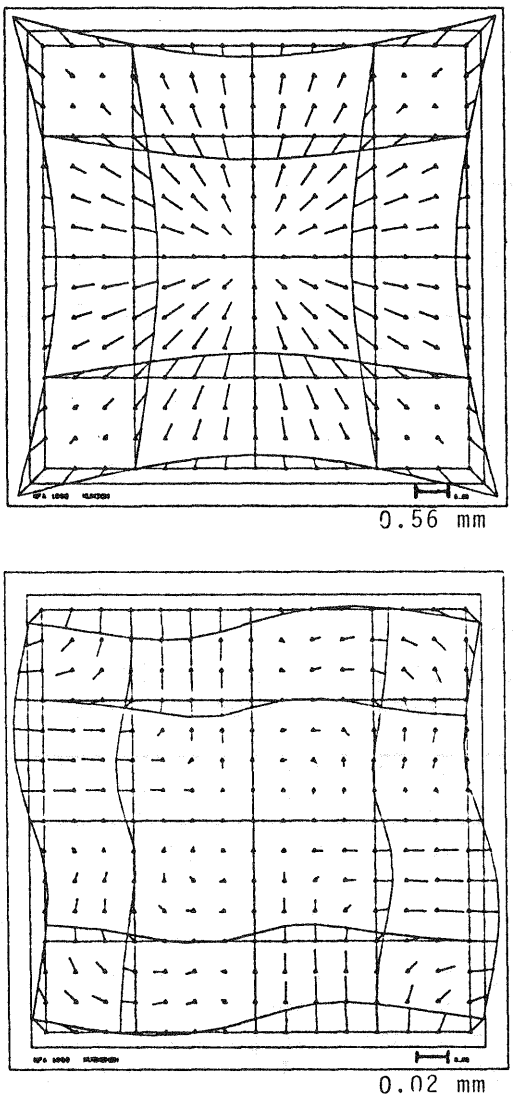


Fig. 3: KFA-1000 block Hannover



upper: including lens distortion
lower: without lens distortion

Fig. 4: KFA-1000 systematic image errors

area	control points	sigma0 [microns]	sx [m]	sy [m]	sz [m]
Hannover	214	19.2	8.1	5.4	36.3
Munich	72	35.6	10.7	10.5	29.9

TABLE 5: bundle block adjustment with KFA-1000 photos

The horizontal accuracy of the adjustments with KFA-1000 photos has not reached the quality of the Metric Camera and the LFC photos, even by the better ground resolution. The geometric film quality seems to be limited. The lower height accuracy is caused by the height to base ratio.

KATE-200

Close to Munich a block has been measured with photos from the three simultaneously used KATE-200 cameras.

spectral range	control points	sigma0 [microns]	sx [m]	sy [m]	sz [m]
510 - 600 nm	48	20.2	32.7	25.5	63.8
600 - 700 nm	47	20.2	29.8	24.3	47.7
700 - 850 nm	42	37.9	47.3	60.5	94.5
all together	49	26.7	29.3	30.1	50.5

Table 6: bundle block adjustment with KATE-200 photos, block Munich

The low accuracy of the photos with the spectral range 700 - 850 nm is caused by the lower resolution ot these photos. But also if the scale difference is taken into account, the standard deviations are exceeding the results achieved by the other sensors. The main reason for this is the lower ground resolution. The identification of control points was very difficult.

SPOT

Two SPOT stereo scenes have been adjusted (Picht 1987).

area	type	base/height	sx [m]	sy [m]	sz [m]
Marseile	panchromatic	1 : 1	10.9	13.7	6.5
Hannover	multispectral	1 : 3.5	11.4	7.4	50.5

Table 7: block adjustment with SPOT scenes

The quality of the control points in the Marseile area is limited. So again we have the problem that this will limit the results. The limited height quality in the Hannover area can be explained by the lower base to height ratio and the lower resolution of the multispectral scenes. For photogrammetric purposes only panchromatic scenes with a base to height ratio of 1 : 1 should be used.

6. Comparison of Sensors

The results of the block adjustments are partially effected by the quality of the ground control. By this reason only the best results should be compared.

sensor	area	scale number	height/base	sx,y [m]	sz [m]
MC	N. Germany	820 000	3.3	7.7	20.2
LFC	Alps	770 000	1.6	5.8	8.6
KFA	Hannover	275 000	8.3	6.9	36.3
KATE	Munich	1 400 000	2.8	27.2	47.7
SPOT	Marseile	400 000	1.0	12.4	6.5

Table 8: results of block adjustment

The positional accuracy of the bundle block adjustments with MC, LFC and KFA photos are not so much different. The differences can be caused by the quality of the control points. The positional accuracy of the SPOT evaluation seems to be influenced by not compensated remaining dynamic effects. The results achieved with the KATE-200 can not be compared with the results of the other sensors. Photos taken with the KATE-200 should not be used for mapping if other space images are available.

The height accuracy is mainly determined by the height to base ratio. The results achieved with SPOT using the maximal angle of incidence was optimal, followed by the LFC. The KFA-1000 has not been designed for optimal height accuracy. A disadvantage of the line sensor images from SPOT satellite is the need of a higher number of control points. At least 10 control points are necessary for the exact determination of dynamic effects.

7. Mapping

The geometric conditions for mapping are similar to the block adjustments. Exactly defined points can be measured with the same positional accuracy. The standard deviation of heights usually is less accurate by the factor up to two in relation to the bundle block adjustment. In general there is no problem of the positional accuracy for mapping in scale 1 : 25 000 or smaller. The vertical accuracy on the other side is limited by mapping with space images. For map revision the vertical component is unimportant.

The main limitation for horizontal mapping with space images is the ground resolution. A direct comparison of ground resolution is not easy, not only the resolution, but also the contrast is important. So the digital Spot data can not be compared directly with the ground resolution of photos. It is not correct to multiply the pixel size by the Kell factor (10 m pixel * 2.8 = 28 m ground resolution) because with digital data the contrast can be improved. A comparison of the space photos resulted in the best interpretation of objects with photos from KFA-1000, followed by SPOT, LFC, MC and KATE-200. The ground resolution of the MC is limited because no forward motion compensation (FMC) was used. In the planed reflight of MC a FMC shall be used, so these photos will enable a similar posibility of interpretation like SPOT.

8. Conclusion

Space images are available today and give a large progress in mapping and map revision in scales 1 : 50 000 and smaller. The positional accuracy for such maps can be reached without problems. The accuracy in height is limited by the base to height ratio which is optimal for SPOT. But the difference in time between the recording of the same area by SPOT can cause some problems - the reflectance of the ground can change.
The handling of space photos is more easy like the handling of SPOT images. For SPOT more control points are necessary.

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