Aerial Triangulation of SPOT and Aerial Photography

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0. Abstract

Aerial triangulation of SPOT and high altitude photography is performed
using homologue points identified both in SPOT and aerial photographs.
The data aquisition has been done based on digtital data with the Context
Mapper stereo workstation and with recorded photos by means of an analytical
stereo plotter. The recorded data have been improved by reseau measurements
and in addition an image coordinate correction has been done based on
the known angular speed of the satellite.

1. Introduction

A main problem of handling space images are ground control points with
sufficiant accuracy. For test purposes a block of high altitude photographs
has been used as base for the handling of SPOT images in the region of
Hannover. These photos, flown by the DFVLR, Oberpfaffenhofen with a
RMK 8.5/23 do have a scale 1 : 135 000. The used color film Kodak 2443
has a low resolution, so the result of the block adjustment with these
photos was limited to a ground accuracy sx = sy = +/- 1.5 m and sz = +/- 2.5m.
But nevertheless this accuracy is much better than the accuracy which can
be achieved by SPOT data, so a combined adjustment of both different data
sets was useless. The control points achieved by this bundle block adjustment
have been completed by control points digitized from maps 1 : 5000 with
a quality of sx = sy = +/- 1.5 m and sz = +/- 0.5 m.
The SPOT data are handled as well as digital data in the Context Mapper
stereo workstation and as photographic material in an analytical stereo
plotter. The recording of digital SPOT data to film is influenced by the
geometric quality of the recording device. This can be checked by reseau
points, which have been added digitaly to the data set before recording.

In general known geometric conditions should be used in data handling. One
of this known condition is the angular orientation of the SPOT satellite.
Corrections of photo coordinates have been computed based on the integrated
angular speed of the satellite.

2. Test Area

Four different SPOT scenes have been used in the region of Hannover.

scene	type	scene time	incidence angle
1	multispectral	1986 June 28	R 8.0 degrees
2	multispectral	1986 June 17	L 8.6 degrees
3	panchromatic	1986 June 17	L 8.6 degrees
4	panchromatic	1986 August 14	R 11.1 degrees

Table 1: used SPOT scenes

3. Data Aquisition

The measurement of photo coordinates can be done purely digital by means of an digital image display or based on recorded photos with usual photogrammetric equipment. The measurement in an image display system has to be done with subpixel accuracy. It is not enough to specify just the pixel adress of the location of control and other points.
A measurement with subpixel accuracy can be done with the Context Mapper stereo work station (Lohmann et al 1988).
Digital stereo work stations like the Context Mapper are not very often available, so the measurements have been done also based on recorded data. The used SPOT scenes have been recorded at the DFVLR on a FIRE film recorder. Just a simple histogram linearisation was used for contrast improvement. The geometric quality of this device was unknown, so a regular grid of pixels was used as reseau grid.
The photo coordinates have been measured with the Hannover program for computer supported data aquisition B159 (Jacobsen 1988) at the Planicomp based on predigitized points and the known positions of the reseau points.

The exact identification of control points in small scale photos is difficult and time consuming. In the case of multispectral SPOT images with a pixel size of 20 m only large objects can be used as control points. But also in panchromatic scenes, the point location includes some problems. In space images street crossings in country side are qualified objects, such crossings have high contrast to the neighbourhood and can be identified without problems. In line sensors a high contrast has the disadvantage, that the object centre can be shifted in the direction of the CCD line readout. Such dislocations can not be seen by the operator.
Opposite to the experience with other space images, for SPOT images it is better to use control points in cities or villages.

At the Planicomp the images have been measured twice. The pointing accuracy of +/- 5.4 microns exceeds the usual values in photogrammetry, but this is caused by the problems of exact point identification.

4. Preparation of Image Coordinates

The geometric problems of film recording have been solved by a regular grid of marked pixels. The displacement of such reseau points are pointing out the quality of the used recording device.
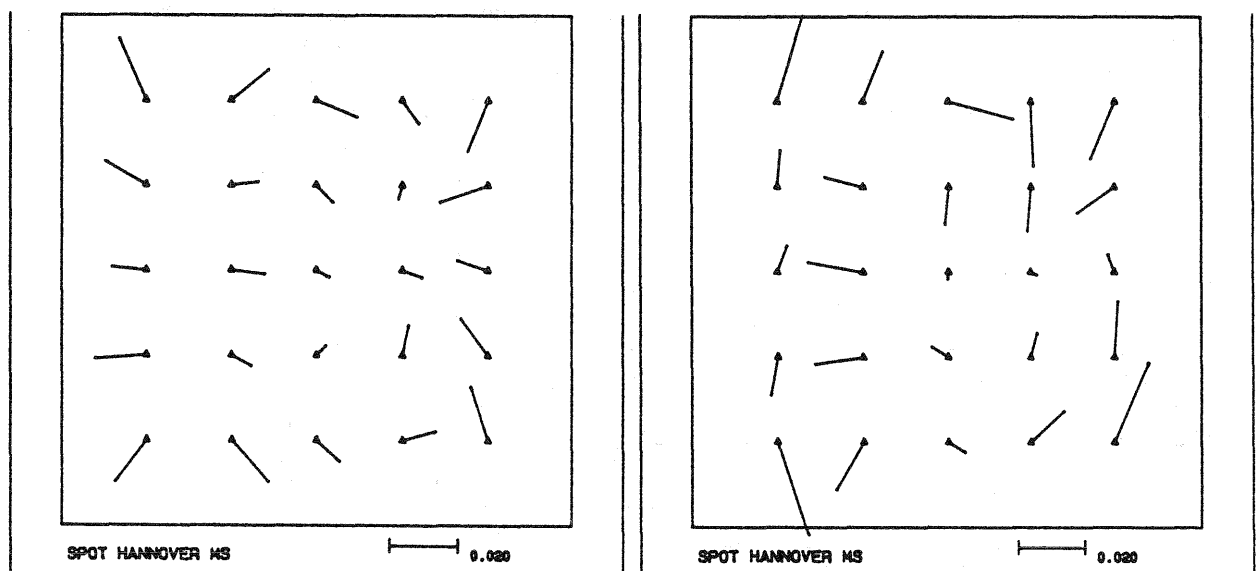

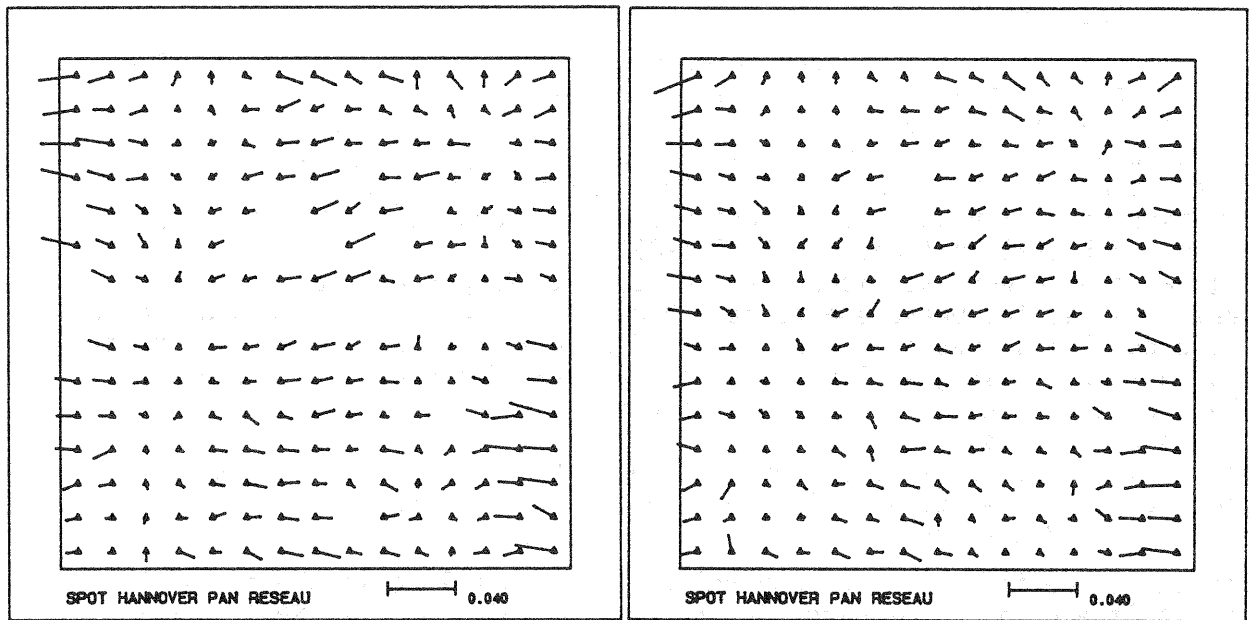Figure 1: differences at reseau points   left: scene 1 right: scene 2

Figure 2: differences at reseau points   left: scene 3 right: scene 3

The both multispectral scenes are recorded together at the same day, even later the both panchromatic scenes.
The displacements of the both multispectral scenes are similar and much more the values of the both panchromatic scenes. But the panchromatic and the multispectral photos are different.

scene	mean square reseau differences		maximal differences	
	msx	msy	max x	max y
1	9.2	8.7	15.	18.
2	8.8	14.1	20.	30.
3	9.3	2.9	25.	8.
4	8.0	3.2	25.	9.

Table 2: differences at reseau points [microns]

The differences at the reseau points are much more than acceptable, so corrections for photo coordinates have been computed based on bilinear interpolation to the neighboured points. But it is not necessary to use a dense reseau like used for the panchromatic scenes. For the used equipment a reseau spacing of 20 mm is sufficiant and necessary. That means, the reseau grid for the multispectral images was not sufficiant. It is also necessary to have reseau points close to the borders of the images.

The header data are including information about the average yaw, roll and pitch speed. By this information the satellite does not have the same orientation to the nadir from the first to the last line. The average speed has been integrated to angular orientations and the influence of such orientations to the photo has been computed.

scene	max pitch	max roll	max yaw	max x	max y
3	0.0011	0.0001	0.0001	4.	40.
4	0.0006	0.0001	0.0001	4.	23.

Table 3: maximal angular change against first line [degrees] and influence to photo coordinates [microns]

The influence of the angular change to the photo coordinates is not negligible and has been respected. The angular and the reseau corrections are included in program BLPRE of the Hannover bundle adjustment system BLUH.
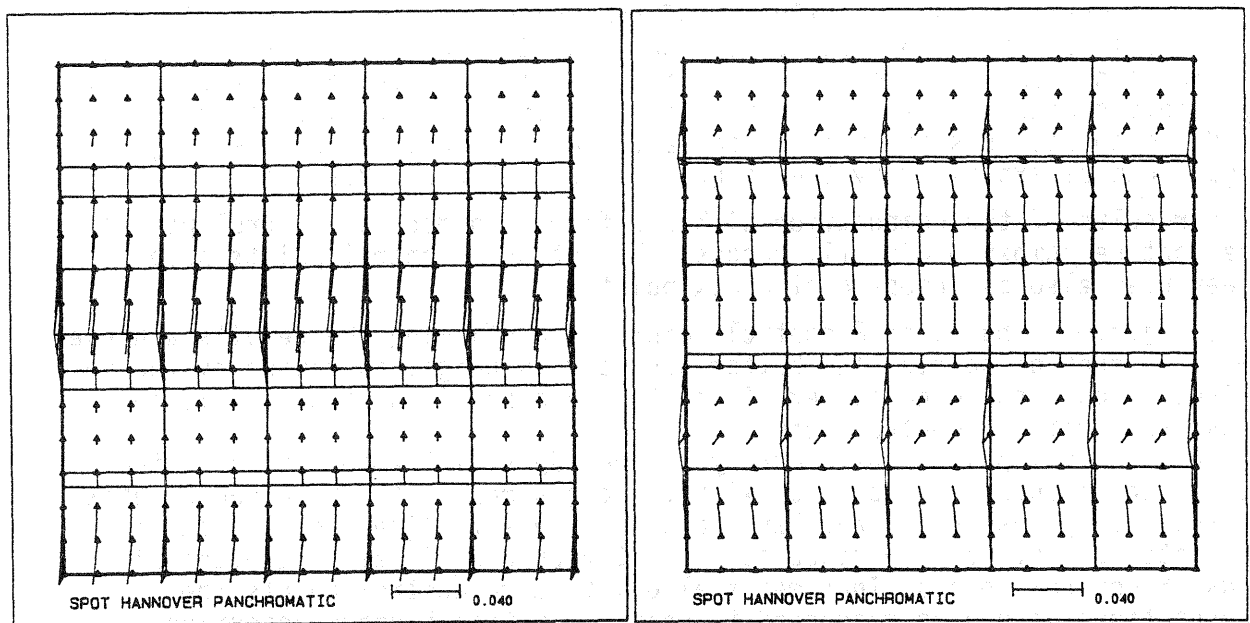
Figure 3: influence of angular speed to the SPOT scene
left: scene 3　　　right: scene 4

5. Blockadjustments

Bundle block adjustements have been computed with the Hannover program
BINGO.

scenes	control points	sigma 0	msx	msy	msz
1/2	10	10.7	11.4m	7.4m	50.5m
1/2	6	10.8	13.9m	8.2m	53.3m

Table 4: mean square differences at independent check points of the
multispectral scenes

The limited quality of the block adjustments with the multispectral
SPOT scenes are corresponding to the expectations. The low resolution of
20 m pixel size do not allow an accurate point identification. The
differences in height can be explained by the height to base ratio of
3.4 : 1. The low value of the standard deviation of unit weight sigma 0
indicates just the minor meaning of this value if weights have been used
in the adjustment.

photo coordinates	scenes	control points	sigma 0	msx	msy	msz
uncorrected	3/4	20	11.2	5.7m	4.7m	21.5m
reseau correction	3/4	20	11.5	5.4m	4.8m	22.0m
reseau + angular corr.	3/4	20	8.1	5.7m	4.4m	22.6m
uncorrected	3/4	8	12.4	6.2m	4.0m	18.4m
reseau + angular corr.	3/4	8	8.3	5.0m	5.1m	19.1m
uncorrected	3/4	6	13.0	12.0m	4.7m	18.6m
reseau + angular corr.	3/4	6	8.5	6.0m	5.7m	22.2m

Table 5: sigma 0 and mean square differences at independent check points
of the panchromatic scenes

There is more or less no influence of the photo coordinate correction to the result of the bundle adjustment based on 20 control points. Just sigma 0 is reduced from 11.2 microns to 8.1 microns. This is caused by the additional parameters used in the adjustment, they are able to fit systematic effects and the corrections are mainly regular. The lower quality of the heights again can be explained by the height to base ratio of 2.9 : 1.

The results of the computation with a different number of control points can not be compared directly because the not used control points have been used also as independent check points.

The adjustment based on 8 control points is confirming the results achieved with 20 control points. The better accuracy in height is caused by the not directly corresponding number of points. In general the accuracy is not less than with 20 control points.
With 6 control points the accuracy of the adjustment with not corrected photo coordiantes is less than with the adjustment with photo coordinates corrected by reseau and angular change of the satellite. The systematic effects can not be determined sufficiantly by additional parameters with just 6 control points. That means also with more control points the corrections should be respected to enable a better blunder detection.
The blunder detection by robust estimators has had some problems with the uncorrected data.
The differences at independent check points are also influenced by problems of point identification which is influenced by the time difference between both scenes of 2 month. The color of some fields has changed from dark to bright.
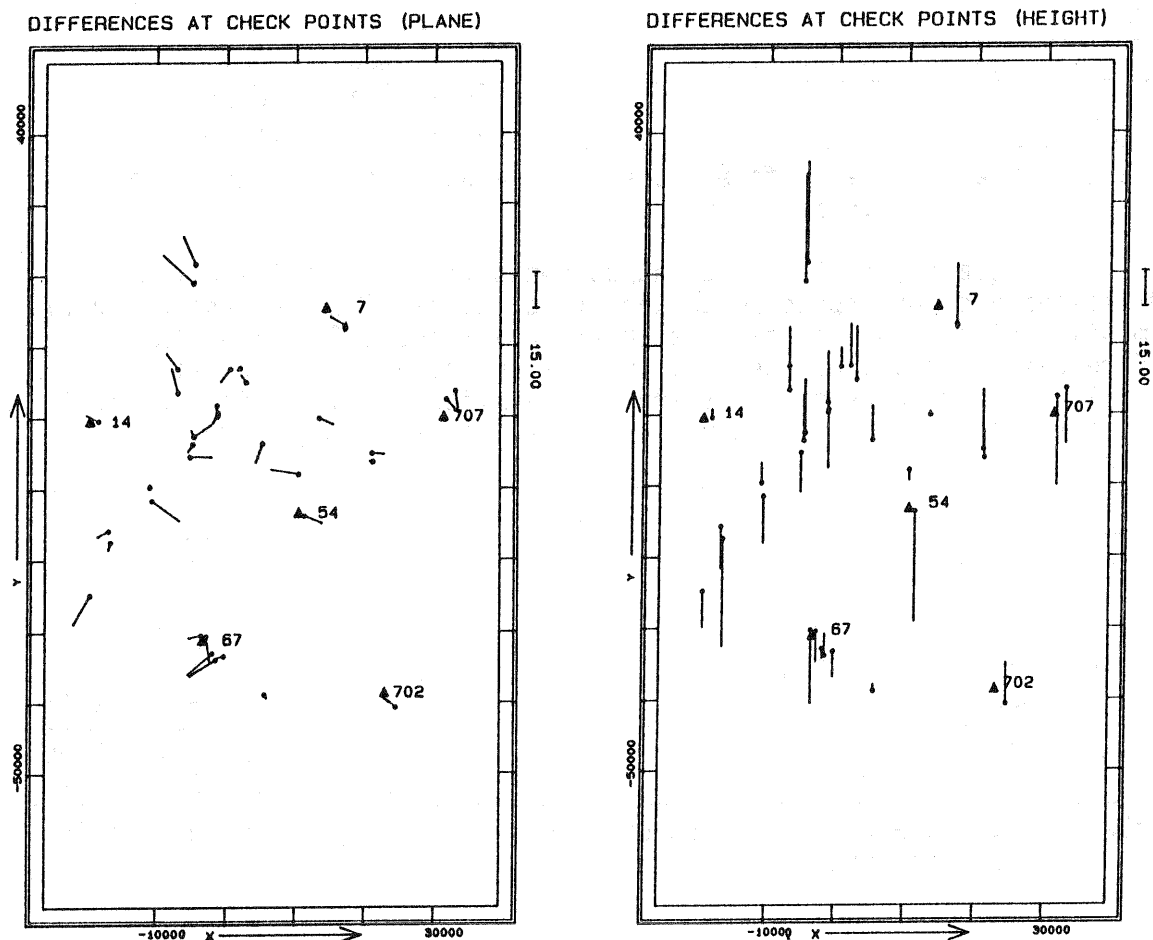

Figure 4: bundle adjustment with 6 control points

6. Conclusions

The block adjustments with the SPOT data have demonstrated the geometric potential of the images. The geometric effect of film recording can not be neglected and should be respected by using reseau points. Even the slight angular changes during one scene should be used as geometric information.

References

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