SIMPLE SOLUTION OF THE SPECIAL IRS-1C-PAN-CAMERA PROBLEMS

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ABSTRACT - The IRS-1C and the –1D PAN-cameras do have a combination of 3 linear CCD-lines instead of just one. The relation between the 3 CCD-lines is not stable and differs from orbit to orbit. This causes some special geometric problems which can be solved by means of control points or partially by a combination with LISS-III-images of the same satellite. There is no commercial software package available which can respect such special geometric conditions in a digital photogrammetric stereo workstation. With a resampling of the 3 sub-scenes together to a single image this problem can be solved. In a not mountainous area such prepared images can be handled also with a simple perspective mathematical model only with negligible loss of accuracy.
The results of bundle orientations based on a rigorous mathematical model are shown together with the estimation of the geometric loss by handling the images in a stereo workstation. In addition the geometric and mapping potential is compared with other space sensors.

1 - INTRODUCTION

The high resolution PAN-camera of the Indian Remote Sensing Satellite IRS-1C, launched in December 1995 and the identical IRS-1D, launched in September 1997, is enabling a stereoscopic coverage by changing the view direction across track up to +/-26°, corresponding to SPOT. The swath size is 70km in the nadir direction with 5.8m pixel size. 3 CCD-lines, each with 4096 pixels, are combined [Joseph 96]. There is a small overlap of the 3 lines, so the effective size of the combination corresponds to approximately 12 000 pixel.

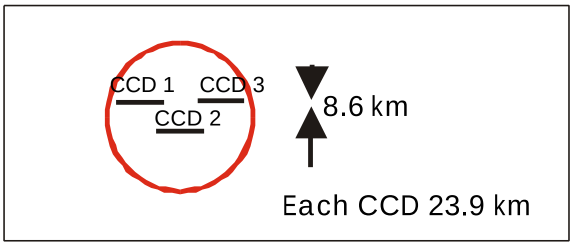
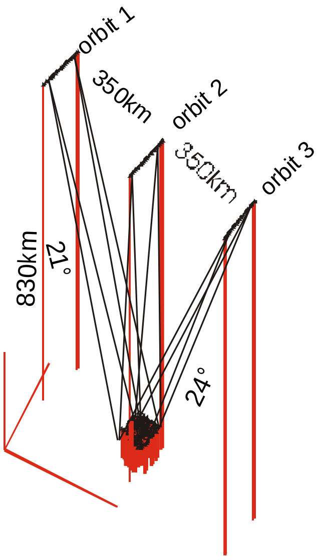


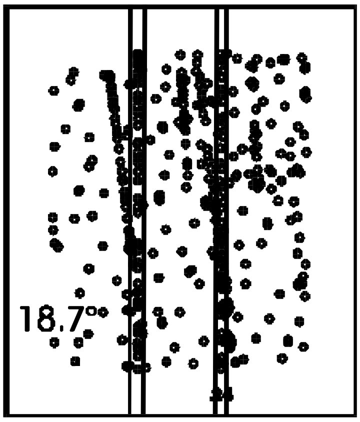
Fig.1: separation of the 3 CCD-sensors in the PAN-camera

The imaging delay of the center CCD-line is identical to a distance of 8.6 km in the orbit. A ground point will be displaced by 10m in the orbit direction if the point is located 1000m above the control points or 5 m in relation to the mean of the combined lines. Usually this effect is not so important. Larger problems are caused by the fact of a not fixed geometric relation of the 3 single CCD-lines.

2 – GEOMETRIC ANALYSIS

By a cooperation with the Space Application Centre, Ahmedabad, 3 full scenes of the area around Hannover were available. The first with a view direction of 18.7° was taken at December 1996, the second as nadir view was taken one day later and the third again one day later with a view direction of –20.6°. The second scene is partly covered by clouds. A disadvantage is the low sun angle of ~13°, the long shadows caused some difficulties for the exact point identification.





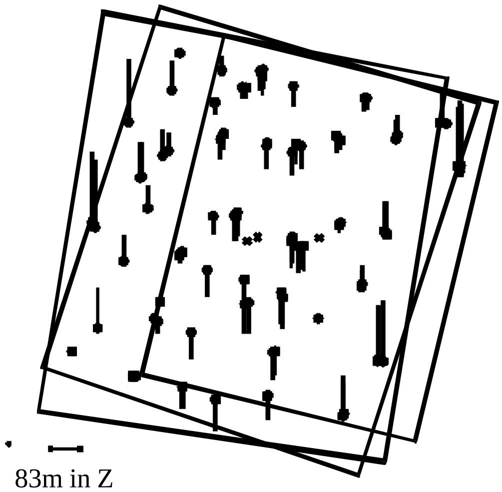


Fig. 2: configuration of the data set Hannover

Fig. 3: measured image points scene 1

Fig 4: area covered by the 3 scenes with control points and DZ

By means of tie points the 3 sub-scenes (see overlapping areas marked by double lines in figure 3) of the 3 complete scenes have been shifted together, this was possible with a standard deviation of the observations between ±0.2 up to ±0.6 pixel. The shift values of the 3 full scenes do have significant differences up to 7 pixel for the x- direction and up to 30 pixel for the y-direction. In addition to a shift, the 3 CCD-lines of the PAN-camera may have a different focal length (identical to differences in the scale) and also a rotation of one CCD-line against the other in the focal plane.
At first after the shift of the 3 sub-scenes to full-scenes, a bundle block adjustment has been made with program BLASPO of the Hannover program system for bundle block adjustment BLUH. BLASPO is using the colinearity equation for the combined CCD-lines. The relation of one line to the other is based on the location the projection centers on a ellipse in the inertial space. In general, this is the most rigorous mathematical model for satellite line scanner images. Deviations against the mathematical model are compensated by additional parameters. For satellite line scanner images affinity and angular affinity are required as additional unknowns. By affinity errors differences in the speed, focal length or a continuous rotation of the satellite in the orbit direction can be compensated, the angular affinity is determining a not perpendicular orientation of the CCD-line against the orbit.
An adjustment of the 3 IRS-1C scenes with 90 control points resulted in a sigma0 of 4 pixel and root mean square discrepancies at the control points of RMSX=9m, RMSY=10m and RMSZ=83m. The differences in the height can be seen in figure 4. It clearly indicates positive errors on the left and right hand side of the scenes and negative errors in the center, that means, the focal length of the sub-scenes are not identical. In addition, the horizontal results are indicating a rotation of the CCD-lines of one against the other in the focal plane. By this reason special additional parameters (see table 1) are included in the adjustment [Jacobsen 98]. The parameters 11 and 12 can compensate differences in the focal length and the parameters 13 and 14 can compensate the rotations in the focal plane.

`1  Y = Y +  P1 * Y`	coordinates corresponding to pixel size 7µm

```
 2  X = X +  P2 * Y
....
11  X = X + P11 * (X-14.)     if x >  14.
12  X = X + P12 * (X+14.)     if x < -14.
13  Y = Y + P13 * (X-14.)     if x >  14.
14  Y = Y + P14 * (X+14.)     if x < -14.
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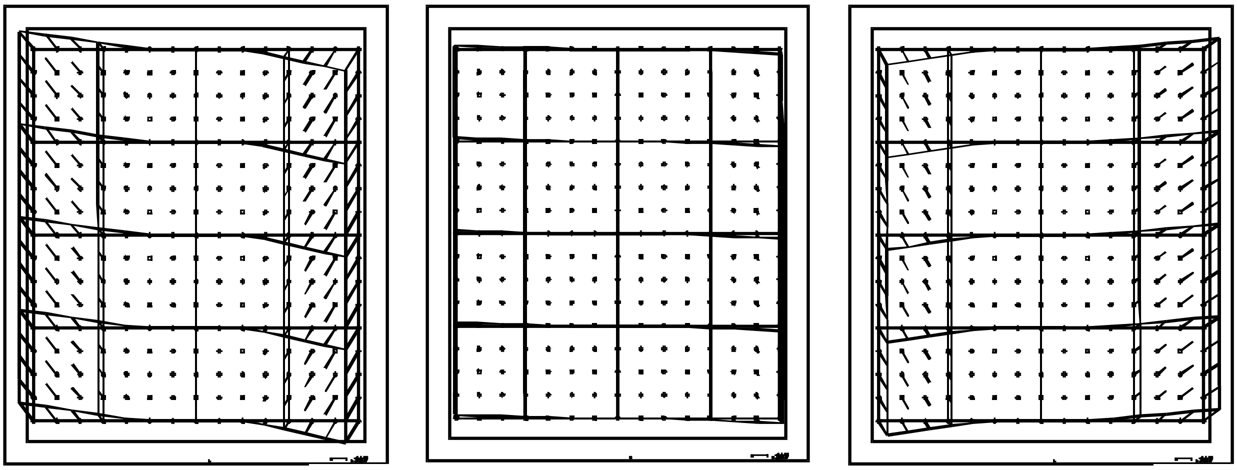
table 1: additional parameters of program BLASPO

An adjustment with these special additional parameters, used together for all 3 full scenes has only reduced the discrepancies in Y from 10m to 7m. It indicates different values of the additional parameters for all 3 full-scenes, so an adjustment with the listed additional parameters, but individually for every scene, has been made. This resulted in a sigma0 (accuracy of the image coordinates) of 1.1 pixel and at the control points to RMSX=7.1m, RMSY=5.0m and RMSZ=9.7m what is in the range of the expectations. The discrepancies in X and Y are corresponding to 1 pixel on the ground and the Z-discrepancies to 1.7 pixel, or if the height-to-base-relation is respected, to an x-parallax of 1.4 pixel. With other space data better results in relation to the pixel size have been achieved, but the test data set was influenced by the very low sun elevation causing long shadows, so the identification of the control points was difficult. An adjustment with 9 control points, under the same conditions, resulted in similar results at the independent check points, based on 5 control points the RMS-values raised 50%.



left scene 20 pixel center scene 20 pixel right scene 20 pixel

Fig. 5: influence of the special additional parameters for IRS-PAN-images to the scenes

The influence of the additional parameters to the scenes, shown in figure 5 (“systematic image errors”) is quite different for the scenes, it seems to be dependent upon the view direction. An effect up to 20 pixel is reached. For all 3 scenes the systematic image errors do have the opposite sign on the left hand side than on the right hand side, but the size is not the same.

If no actual orbit information will be used, like in this test, 2 control points in addition to the usual 3 points are required for the determination of the special additional parameters. Even with the combination of the 3 full scenes (see figure 4) it is not possible to determine the special image deformations with a sufficient accuracy just based on 3 control points. A combination with the unique geometry of LISS-III-images can partially solve the problem, but nevertheless it is not so easy to identify tie points between PAN-images and LISS-III-images because of the 4 times larger pixel size of LISS-III. If only one PAN-scene will be used, ortho-images have to be determined in using existing height information. This is possible with an accuracy of 1.6 pixel just based on 3 control points but without any reliability, a sufficient over-determination should be used.

3 – HANDLING IN DIGITAL STEREO WORKSTATIONS

If only sub-scenes are used, they can be handled in the same way like usual satellite line scanner images, for example like SPOT-scenes. The deviation from one sub-scene to the other are compensated by the exterior orientation. The handling of full scenes in a stereo mode has to respect the mentioned geometric relations, otherwise the vertical accuracy cannot be accepted. If only the horizontal information is important, the influence of the deviations are still limited. Based on the systematic errors, determined by the additional parameters, a geometric resampling of the sub-scenes to a full-scene is possible. Such combined and improved full-scenes do have the same geometric behavior like satellite line scanner images based on just one CCD-line. The standard software for handling satellite line scanner images in digital stereo workstations can be used. We do have the same situation for image matching.
If only the software for handling perspective images is available, a geometric transformation has to respect also the earth rotation, earth curvature and net projection and can be correct only for a defined height level.

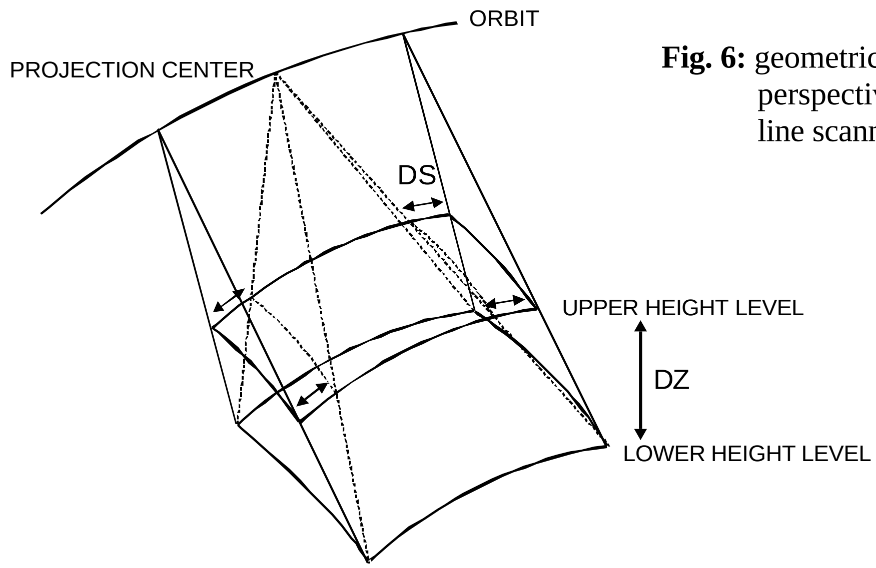
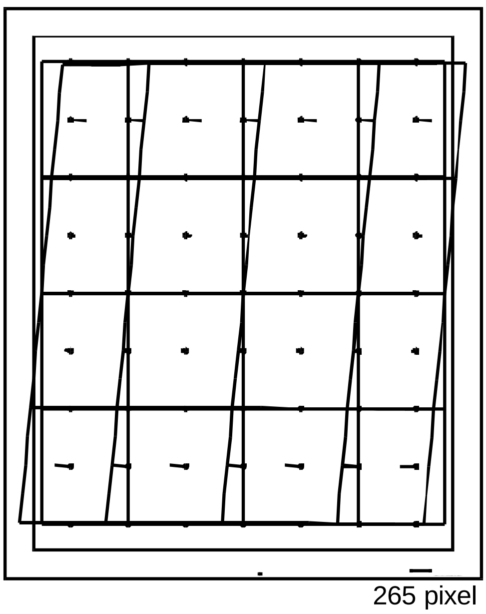


Fig. 6: geometric differences between perspective model and satellite line scanner geometry



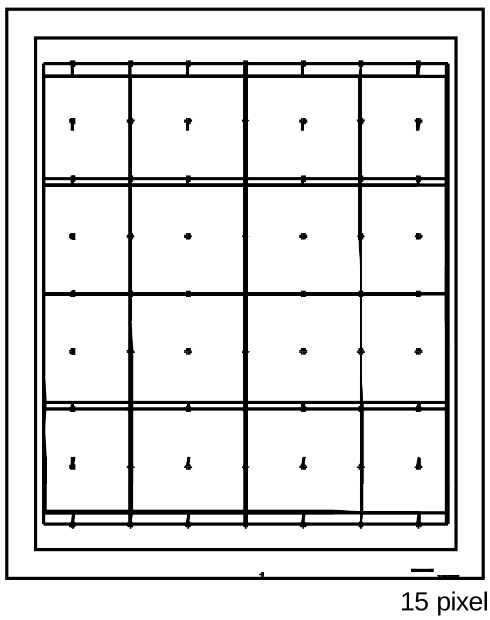


Fig 7: differences perspective model against Satellite line scanner geometry Z = 0m scene 2

Fig 8: differences height level 1000m against height level 0m for scene 2

The differences between the satellite line scanner geometry and the perspective model for the center scene of the test data set can be seen in figure 7, it goes up to 265 pixel. These differences

can be respected in a geometric resampling of the scene. As shown in figure 6, for a different height level, the differences between the satellite line scanner geometry and the perspective model does have mainly differences in the orbit direction of the scene, shown also in figure 8 for the center scene of the test data set and a height interval of 1000m. The differences are going up to 15 pixels. That means, if the resampling will be done for a height level of 0m, a position located at a height of 1000m and in the first or last line of the scene will have a horizontal displacement of 15 pixels or 87m. Also the height will be influenced caused by the not parallel orbit directions of stereo scenes. In the case of the test data set it goes up to DZ=15m. Of course if a special software is existing, which can respect the differences of satellite line scanner images against the perspective geometry in the loop of the stereo workstation, by the use of 2 correction grids for different height levels, with such an additional module for the perspective geometry, satellite line scanner images with any geometry can be used without problems in using the perspective module with local corrections. Such a solution has been developed by the University of Hannover for an analytical plotter [Picht 87].
In several areas the differences in the height are much smaller, for example in the area of Hannover, covered by the test scenes, the height variation is limited to 100m. Against a mean reference height level, the height variation is just 50m and this is causing in maximum errors in the location of 4m or in the height 0.7m if a perspective model will be used together with the resampled IRS-1C-scenes. Such maximal discrepancies are negligible. By this method the special geometric problems of IRS-1C can be solved together with a simple handling with the standard software of every stereo workstations. Only the a special software for the geometric resampling is required in addition to the bundle orientation with a program like BLASPO / BLUH.

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