Restitution of LANDSAT - MSS Imagery Using an Analytical Plotter of the Federal University in Curitiba/Brazil

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1. Background

Since more than 12 years, a Master Course in Geodesy and Photogrammetry is offered at the Federal University in Curitiba (Paraná/Brazil). This Course is the base for a project of technical collaboration, established by the Federal Governments of Brazil and Germany, starting in 1981. In order to allow high quality education and research, beside other instruments, a ZEISS PLANICOMP C 100 Analytical Plotter System was installed, including a HP 1000/45 processor and a DZ 7 plotting table.

Differing from Industrial Countries, Third World Countries have to make in a different way use of high sophisticated technology. Consequently, the Planicomp System in Curitiba is extensively used, processing even geodetic data (Doppler) and data from electronical tacheometers, apart from "classical" photogrammetric tasks like Bundle Block Adjustment and photogrammetric mapping. Having no image processing system available, remote sensing data too was processed at the analytical plotter, though this instrument is not specificly designed for that application. This, however leads to many interesting and useful results, which are to be presented in this paper.

2. Use of LANDSAT - MSS Data in Brazil

Brazil was the first nation outside the USA to build a LANDSAT receiving station in the center of gravity of the South American continent. Originally digital, LANDSAT MSS data pushed the development of digital image processing methods in the whole world. In Brazil a special image processing laboratory was established at the INPE (Instituto Nacional de Pesquisas Espaciais) in São José dos Campos, 250 km south of Rio. Being a central institution in a huge country, it can of course not serve adequately all potential users of digital MSS processing.

There are two ways out of that situation. First, any local institution may use its own central computer for digital image processing (e.g. BERUTTI 1984). Second, the user simply works with the photographic MSS imagery offered by INPE. Up to now the latter option is dominating and actually having enormous important applications in Brazil, even if only applying visual interpretation methods.

Processing photographic MSS imagery using a photogrammetric stereoplotter has yet not be done frequently (one exception see CLERICI 1980) though there obviously exist some advantages: The extraction of semantic image information has to be done visually, however the result fits geometrically to a map of arbitrary scale, and specific areas can be simply measured. Because of a rigorous coordinate reference system, temporal image series can be mapped without difficulty (see ROCHA 1983).

3. Some geometric Considerations

The ZEISS Planicomp System has been designed for processing conventional photogrammetric imagery, which follow the geometric laws of central projection, expressed by the collinearity equations

$$\begin{pmatrix} x' \\ y' \\ -c \end{pmatrix}_i = \frac{1}{\lambda_i} \; A \begin{pmatrix} X_i & - X_o' \\ Y_i & - Y_o' \\ Z_i & - Z_o' \end{pmatrix} \qquad (1)$$

,

where $(x', \; y', \; -c)_i^T$ is an image point, λ_i a scale factor, A a rotation matrix, $(X'_o, Y'_o, Z'_o)^T$ the perspective center and $(X, Y, Z)^T_i$ a point on the ground. For opto-mechanical scanners, the image geometry is

$$\begin{pmatrix} 0 \\ c \sin \theta \\ -c \cos \theta' \end{pmatrix}_i = \frac{1}{\lambda_j} \; A_j \begin{pmatrix} X_i & - & X'_{oj} \\ Y_i & - & Y'_{oj} \\ Z_i & - & Z'_{oj} \end{pmatrix} \qquad (2)$$

(see KONECNY 1972). This rigorous expression incorporates the scan angle θ and the time - dependency of the parameters indexed by j. The x' - coordinate is equivalent to the time. Anyway, the formulas (1) and (2) look somewhat similar. They can for practical use indeed be treated as identical, when introducing the following restrictions:

a) time invariant parameters
b) small scan angle
c) scan frequency, instanteneous field of view, platform speed and altitude in correspondance.

a) and b) can be fully accepted for LANDSAT MSS imagery, item c) only aproximatively. Even small variations of one of the parameters in c) cause, in first order, a scale difference in one direction, i.e. an affinity. The affinity is indeed the most sensitive factor contributing to geometric quality of LANDSAT MSS imagery (BÄHR 1978).

Going back to using an analytical plotter for LANDSAT MSS imagery, we may simply correct any affinity during the absolute orientation, and beside this possibility when plotting at the table, which compensates for (affine) paper contraction. As formula (1) and (2) are practically identical for LANDSAT MSS imagery, we are allowed to process this type of data using an analytical plotter.

When processing LANDSAT data digitally, a second-order polynomial approach is sufficient for most cases:

$$\begin{aligned} X &= a_o + a_1 x' + a_2 y' + a_3 x'y' + a_4 x'^2 + a_5 y'^2 \\ Y &= b_o + b_1 x' + b_2 y' + b_3 x'y' + b_4 x^2 + b_5 y'^2 \end{aligned} \qquad (3)$$

The 3 first terms correspond to the affine transformation. The second-oder polynomial approach assumes still more restrictions:

d) nearly vertical view (A ≡ I)
e) terrain height differences below ca. 1000 m.

If we may accept these restrictions, the approximate model (3) gives the same result as the rigorous model of type (2) (see BÄHR 1978). However, the earth rotation effect should be eliminated in advance.

4. Orientation Operations at the Analytical Plotter

After having proven, that we are in principle allowed to process LANDSAT MSS imagery by an analytical plotter, we face more problems, at least for the PLANICOMP, when trying to form a classical "Stereomodel", which of course is not possible with LANDSAT imagery. But the analytical stereoplotter logically requires such a model.

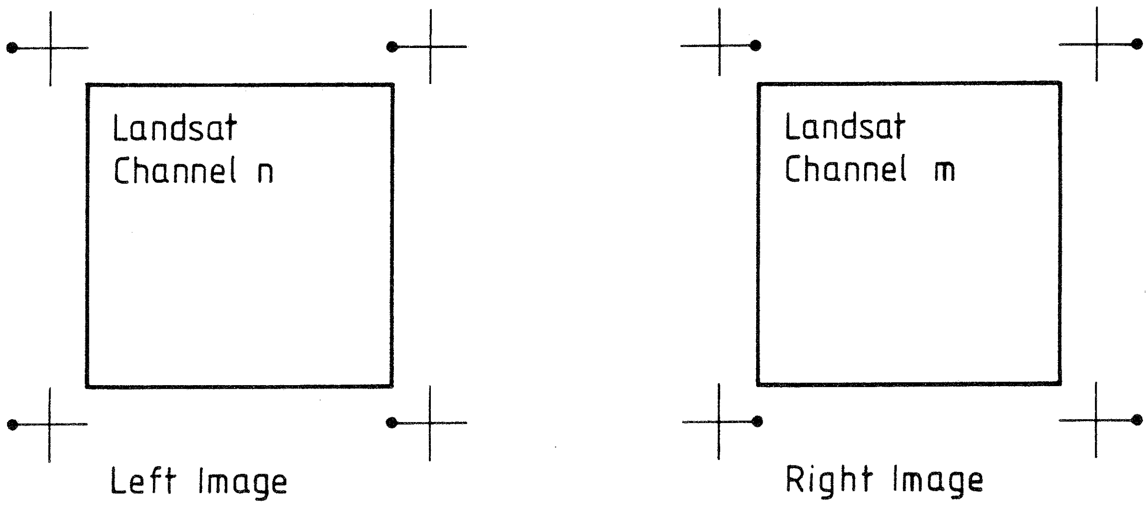

Fig. 1: Measuring "fiducial" marks at left an right image in order to simulate a "base".

In order to overcome this problem, one may artificially introduce a "base" between a left and a right picture and thus simulate a stereomodel. Fig 1 shows how it is done if the base is taken from marginal cross-marks ("first option"). Both images, left and right, are geometrically identical. When measuring the " fiducials " for the interior orientation at the left ends of the horizontal cross bars for the left picture and at the right ends for the right picture respectively, a horizontal parallax is introduced. Afterwards one may go on with the relative orientation as if both pictures would form a stereomodel, using the von Gruber point configuration.

The availability of two images (left and right) which show different spectral channels is very useful during the interpretation process. On the other hand, however, it is also possible to do the orientation with a single image ("second option"). A horizontal parallax can be introduced, without having a reference image, purely by observing the image coordinate display and adding the selected base length for the non-existing picture.

Once the relative orientation performed, the absolute orientation corresponds to the procedure done for conventional stereomodels. As for ground control, one has to observe the requirements for LANDSAT-MSS imagery: more than ten, well distributed points in order to have a certain overdetermination, i.e. control for absolute accuracy. The residuals at the control points allow the analysis of the geometric quality reached in the whole process.

5. Results

5. 1 Orientation Procedures

At the Federal University in Curitiba many LANDSAT "models" have been processed at the Planicomp. The results reported here are from a Master Thesis (CANEPARO 1983) with geoscientific background, analyzing only a very small image section (aprox. 40 km x 40 km). Consequently, the image geometry is very good, anyway better than it could be expected for a full scene.

MODEL SONY LSAT 3.1	OPERATOR SONY	DATE 1983. 9.14.13.31
MODEL SCALE 1: 800000	TABLE SCALE 1: 100000	PHOTO SCALE 1:1150351

ORIENTATION DATA	LEFT PHOTO	RIGHT PHOTO		MODEL
F	836.000	836.000	FLIGHT HEIGHT	962
OMEGA	.009	.015	ABOVE GROUND	
PHI	.077	.077		
KAPPA	-.000	.000	AZIMUT	-10.724
BX	-1.430	1.430	MODEL (XGO	769.71
BY	-.035	.035	CENTER (YGO	7175.91
BZ	-.005	.005	POSITION(ZGO	961.76

MODEL BASE: B =	2.862 (ORTHO)	EARTH CURV.CORR.: R =	6370

ORIENTATION REPORT

ABSOLUTE ORIENT.	USED CONTROL POINTS	PLANIMETRY 22 ELEVATION 22		
	POINT NO.	3001	3004	3035
	POINT NO.	3036	3005	3006
	POINT NO.	3003	3038	3039
	POINT NO.	3012	3010	3037
	POINT NO.	3019	3021	3033
	POINT NO.	3022	3023	3024
	POINT NO.	3026	3030	3034
	POINT NO.	3017		
	RESIDUAL COORDINATE ERRORS		MEAN	MAX
		X	.053	.091
		Y	.055	-.096
		Z	.002	-.005
RELATIVE ORIENT.	USED PARALLAX POINTS	6		
	RESIDUAL PARALLAXES	MEAN	.000	MAX -.000
INTERIOR ORIENT.	USED FIDUCIALS 1234		LEFT	RIGHT
		X-SHRINKAGE	1.005347	1.005340
		Y-SHRINKAGE	1.005577	1.005539
		RECTANGUL.	.00104	.00106

Table 1: Orientation record

Table 1 shows the orientation record. Plotting scale at the table is 1 : 100 000, photo scale is 1 : 1.150 351 (Pixel size 50 µm corresponds to 56 m), determined via ground control, just as flight height (962 km) and the coordinates of the perspective center (XGO, YGO, ZGO). The parameters of relative orientation like

PHI, OMEGA, KAPPA etc. however, are not real but simulated as explained in the preceding paragraph.

RESIDUALS AT CONTROL POINTS AFTER ABSORIENT

I	POINT	DXG	DYG	DZG
1	3001	070	- .021	- .008
2	3004	056	- .024	0 .000
3	3035	045	- .060	- .009
4	3036	- 032	.005	- .002
5	3005	- 003	.087	- .000
6	3006	- 039	- .057	.003
7	3008	- 005	- .003	.009
8	3038	043	.081	.009
9	3039	- 004	.026	0 .000
10	3012	- 064	.079	004
11	3010	- 077	- .050	000
12	3037	- 007	.060	003
13	3019	- .062	- .041	- .003
14	3021	091	.059	.002
15	3033	.035	- .019	- .000
16	3022	- 004	.033	- 002
17	3023	- 015	- .066	- 004
18	3024	046	- .078	- .003
19	3026	- .088	.082	.001
20	3030	- .086	.002	.007
21	3034	019	- .096	.004
22	3017	082	.008	- 015
	MEAN	053	.056	.006

Table 2 : Residuals DXG, DYG, DZG in km units at ground control points after absolute orientation.

Table 2 shows the residuals at the 22 control points after the absolute orientation, Fig. 2 the corresponding vector diagram:

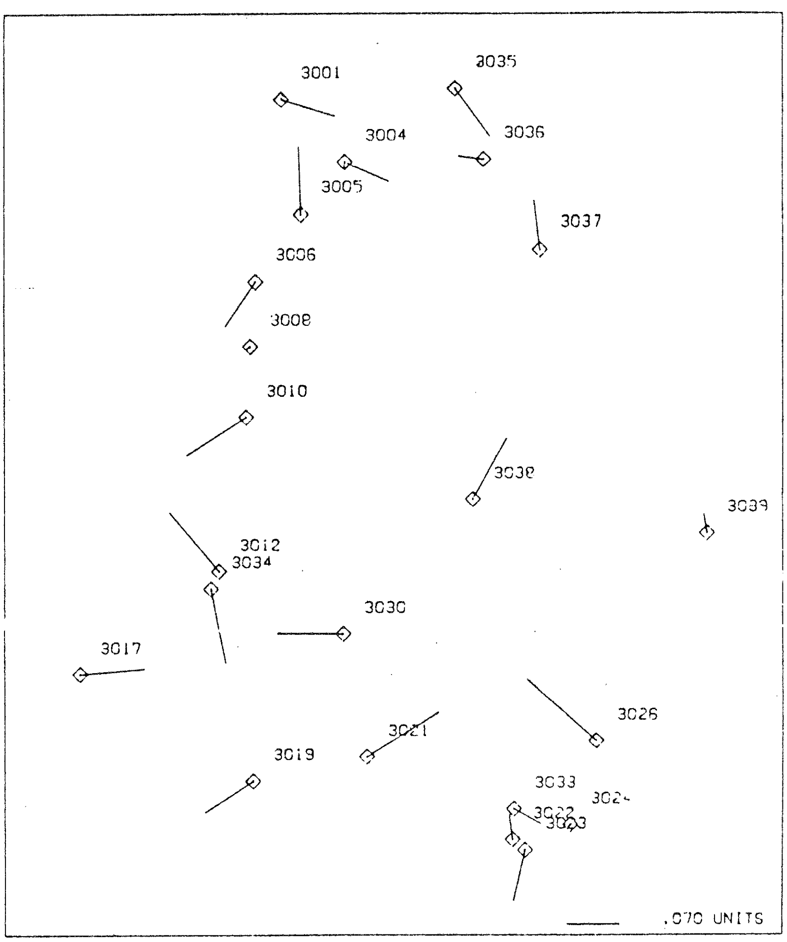

Fig. 2 : Residual vectors at ground control points after absolute orientation (DZ 7 plotting)
⟝—⟞ 100 m as vector
3500 m on the ground

Error magnitude is in the order of what we expect when processing small MSS sections by affine transformation. The vector diagram does not show significant systematic behavior.

The good geometric quality is due to very expensive ground control selection, using 1 : 50 000 topographic maps as a reference system (UTM).

5. 2 Thematic Map

Apart from developing methodology, the final objective of project was to plott a thematic map of the bay of Paranaguá, a region 100 km east of Curitiba. This area is economically very important, incorporating the famous coffee harbour of Paranaguá; it is ecologically very sensitive, as rigorous tree clearing in the nearby Serra do Mar mountains favours erosion and thus sedimentation in the navigable sea channel north and south of Ilha do Mel island.

Fig. 3 : LANDSAT MSS scene section (aprox 40 x 40 km)
Acquisition date: July 15th, 1976
Channel 4,5,6 composite (Original in colour)

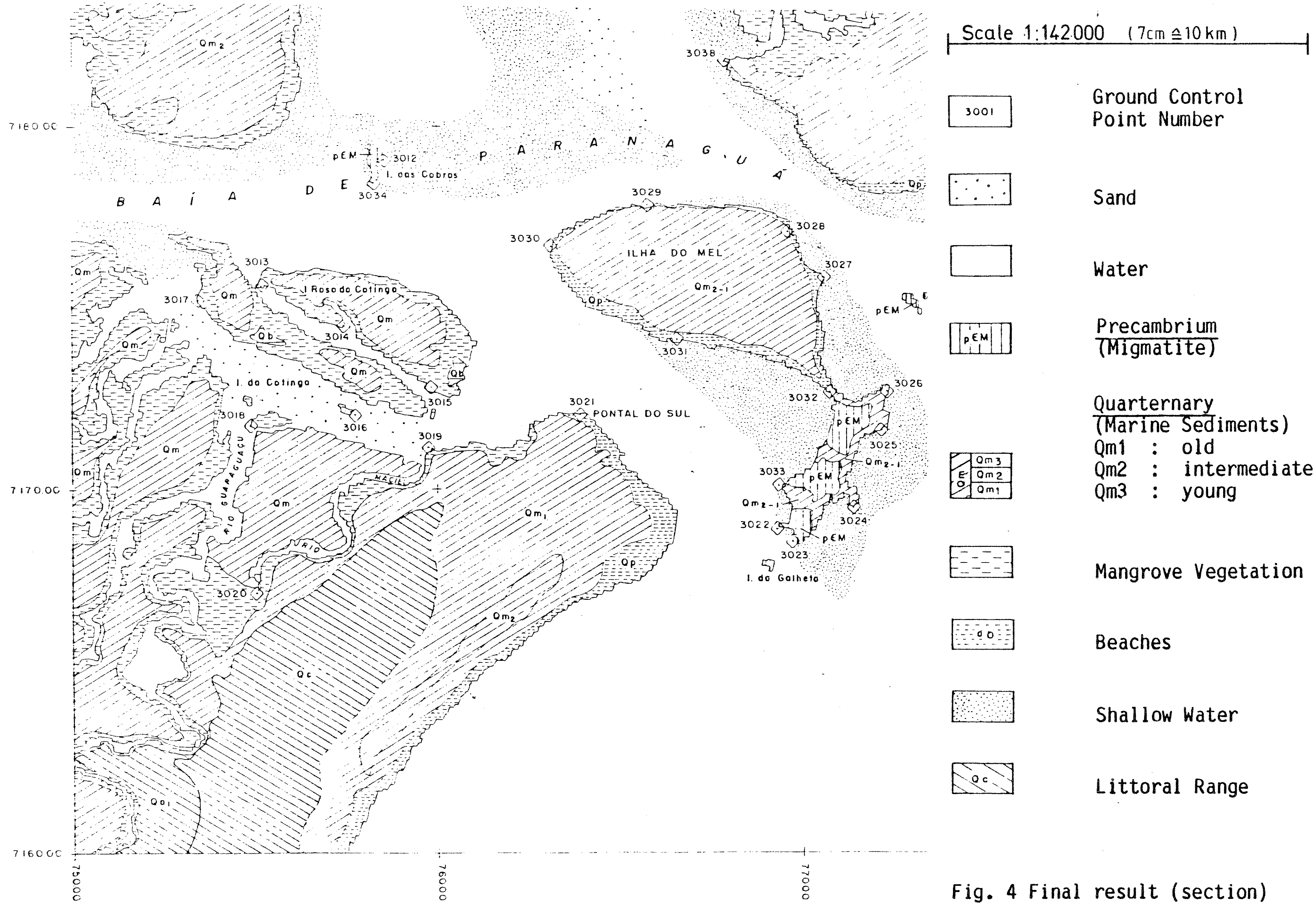

Fig. 4 Final result (section)

Fig. 3 shows the LANDSAT MSS scene section on which the visual interpretation was based. A section of the final map is given in Fig. 4.

The image quality is very bad; a digital multispectral classification with respect to geological and geographical features would not be sucessful. Consequently, the visual interpretation, controlled by a geologist, gives better results. These results are quantized, referring geometically to the UTM map system. The analytical plotter offers by simple subroutines precise determination of distances and areas, without previous digital image processing. The optical components for visual interpretation allow excellent viewing, much better than any TV screen.

One may object, however, that the Planicomp System, designed for conventional photogrammetry and offering a coordinate accuracy of aproximately ± 3 µm, is an order of magnitude "too precise" for LANDSAT imagery with 50 µm resolution. This may change for forthcoming high resolution spaceborne imaging systems; but for these cases the geometrical models will have to be much more rigorously defind than for LANDSAT MSS.

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