Digital Image Processing at the "Curso de Pós - Graduação em Ciências Geodésicas" of the Federal University in Curitiba /Brazil

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1. Introduction

After start of LANDSAT-1 12 years ago, many institutions have been encouraged to get started with digital image processing in earth sciences. Brazil realized the big advantage which the new sensor offered for its own territory. Not only a receiving station was built, but also a data processing facility at the INPE (Instituto Nacional de Pesquisas Espaciais) in São José dos Campos, where the digital image processing system IMAGE 100 was installed.

This institution is the central place for digital image processing for whole Brazil. Though comparatively well equipped, it is impossible to stimulate from that place all potential users in remote parts of the country to apply the new technique and to assist the projects. Consequently, nearly all scientific and technical results presented in the field of digital image processing in Brazil are still directly or indirectly connected with INPE. +)

Because of limited financial resources, Brazil may not develop different centers at once. Moreover, it depends, as hardware and software for digital image processing is concerned, still from the United States and other leading countries in that field.

This paper will try to report some experiences when started with digital image processing at the Geodetic Master Course in Curitiba. There were no special investments done, neither in hardware, nor in software. The programs developed in Curitiba base on general existing facilities, which are widely available. Thus the experiences may encourage other institutions, primarily in Third World Countries to develop a digital image processing facility on its own.

2. Basic Principle

Image processing affords 3 sequential steps of data treatment, which differ completely from each other:

1. Establishing an adequate mathematical model for the desired processing
2. Determination of the specific parameters for that model
3. Execution of the digital process

+) See for instance publications at "II. Simpósio Brasileiro de Sensoriamento Remoto", Brasilia 1982.

The first step affords mathematical reduction of the physical reality; the model is valid for the whole data set of one sensor type. The second step requires statistical evaluation of one special data set, in most cases done by least squares adjustment procedures. Only the last step is specificly what we call "digital image processing"; it is restricted to shifting or modification of pixels in a computer, according to what was determined in 1) and 2). The first two steps require an intellectual solution, the third is only execution.

For all three steps a computer is neccessary (even for the first one when analyzing simulations). Computers are generally available in Third World Countries, too. In the simplest case the configuration is reduced to this scheme:

Input devices	Computer (Software)	Output devices

There is no difficulty using this system for step 1 and 2. For the third step we may assume that the input devices will always offer a magnetic tape unit, which will allow digital image data input. The only critical point is the output device, which always consists of a alphanumerical printer; half-tone images can be simulated by overprints. Digital scanners for image output exist as stand-alone units, but they are not generally available. A much cheaper solution are digital TV screens, which may be photographed to get a hard copy, loosing however geometrical strength.

After all we can state, that digital image processing will be possible even if one only disposes of the above basic computer system, as it is available at many places in developing countries.

3. Concept for Digital processing of LANDSAT MSS Data (CCT, Brazilian Format)

3. 1 Mathematical Models for Geometric Rectification

For geometric correction of LANDSAT imagery we may generally take our choice out of 3 different models (see BÄHR 1978):

a) Rigorous collinearity equations
b) Non - linear polynomials
c) linear models

If one tries, at the beginning, to keep the effort low, linear models have to be selected. However, it is necessary to analyze in advance the geometric restrictions and conditions which are implemented if taken an approximate model instead of a rigorous one. As there did not exist any geometric analysis of LANDSAT MSS image data, which was received and processed in Brazil, this was done for one scene supplied by INPE. Table 1 resumes the obtained results (see DE SANTOS).

Area	Used Points	Control Points	Similarity Transformation		affine Transformation		2^{nd} Order Polinomials		3^{rd} Order Polinomials	
			mx $\pm$	my $\pm$	mx $\pm$	my $\pm$	mx $\pm$	my $\pm$	mx $\pm$	my $\pm$
1	81	81	692	867	185	212	98	67	56	54
	"	16	--	--	--	--	--	--	80	58
	"	12	723	853	186	216	106	80	93	88
	"	09	743	838	187	220	112	82	--	--
	"	04	1158	531	202	247	--	--	--	--
2	21	21	329	406	67	103	57	49	35	44
		9	367	401	70	117	66	53	--	--
		4	578	348	91	120	--	--	--	--
3	22	22	265	375	96	92	45	43	34	33
		9	248	391	97	94	51	54	--	--
		4	655	168	133	123	--	--	--	--
4	22	22	399	448	123	76	51	48	30	31
		9	479	416	131	84	62	57	--	--
		4	440	450	128	91	--	--	--	--
5	16	16	424	525	91	76	29	32	24	22
		9	415	548	97	82	37	45	--	--
		4	340	614	100	88	--	--	--	--

Table 1: Mean root square errors in [m] computed from residuals at ground control points, scene "Curitiba".
Area 1: full scene, Areas 2,3,4 and 5: subscenes ("quadrants")

The test was performed according to prior tests done for LANDSAT MSS data of European origin (BÄHR 1978). Basically, processing Brazilian data leads to the same conclusions drawn from European data:

1. The biggest step in accuracy gain is from similarity transformation to affine transformation.
2. Subscene processing increases accuracy significantly.
3. The number of ground control points is not very important with respect to the final accuracy (nevertheless 10 points are recommended for a whole scene to guarantee statistical fidelity).

There exist, however, some aspects of different behavior of the Brazilian data compared to the European ones:

4. Reduced geometric accuracy of the original image data (referring to similarity transformation: approx. 800 m versus 300 m).

5. Use of 3^{rd} order polinomials instead of 2^{nd} order ones to obtain the usual "standard" accuracy of approx. 50 m

The last point may be due to the UTM coordinate system in Brazil applying 6^{0} distance of the principal meridans, where the distortions of the ordinates Y follow the rule

$$\Delta Y \sim \frac{Y^3}{6R^2}$$

The maximal distortions obtained for MSS data in Germany with 3^{0} distance of the principal meridians (Gauß-Krüger-System) are much below the values which occur in Brazil (see BÄHR 1979).

Linear models for geometric rectification of LANDSAT MSS imagery may correspond to affine transformation, i.e. approximate compensation for earth rotation ("skew") and scale correction for x and y independently. The test shows that we can expect for this case an accuracy of about 200 m for a full scene and of about 100 m for 1/4 scene, or even better when processing still smaller sections (CANEPARO 1983).

3. 2 Concept for Digital Geometric Rectification of MSS Data

After selection of the mathematical model the next step in sequence is to determine the parameters for that model for each single image by least squares methods. As this affords ground control points, the strict procedure often is substituted by only estimating the specific parameters. As far as affine transformation is concerned, the earth rotation effect may be exactly computed in advance; the scale difference ("affinity factor") however, has to be estimated. Usually the factor 79/56 = 1,41 is taken for output of square shape pixel.

The digital data processing sequence for geometric rectification of LANDSAT MSS data is shown by Fig. 1

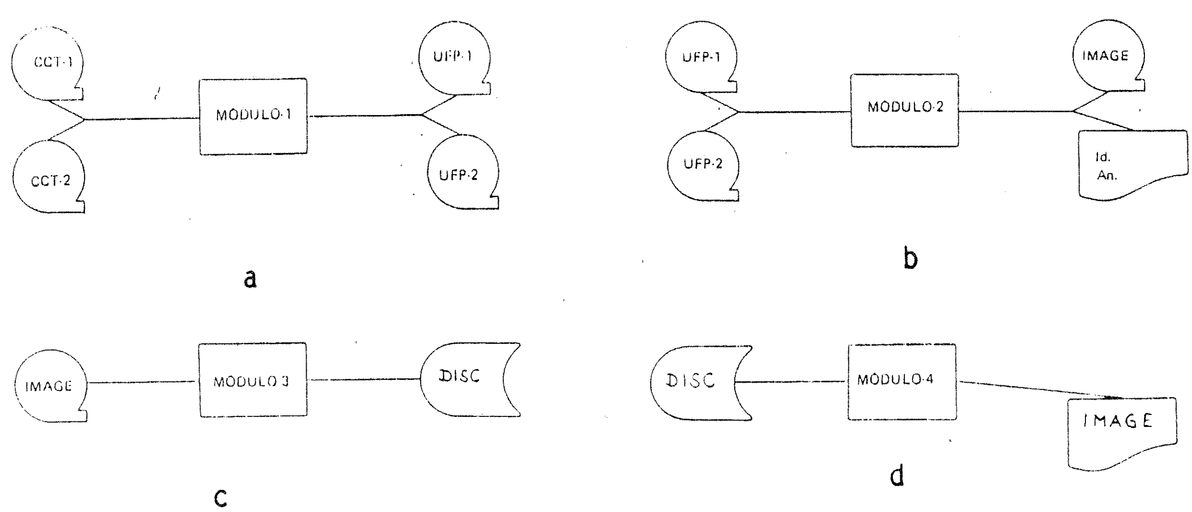

Fig. 1: Processing lines for LANDSAT MSS CCT data, developed at the Federal University in Curitiba (UFPR): SPID-1 ("Software para o Processamento de Imagens Digitais versão 1").

The central computer available at the Federal University of Paraná in Curitiba is a DEC-10. As this machine is not able to process the CCT data format, the tapes first have to be transformed into the UFP format (Fig. 1 a). The next step (Fig. 1 b) is to extract and to store on an auxiliar tape the desired image data. This is more complicated than it should be because of the extremely sophisticated data storing system for the Brazilian tapes (8 separate vertical data bands in each scene with overlap, band - interleaved pixel position). In order to have quick access available to small sub-scenes, one may select areas of interest and store them on the disc (Fig. 1c). The specific image processing finally is executed by module 4 (Fig. 1 d). The software, developed exclusively in Curitiba, consits of the subroutines AMPLIA, SKEW, STREW and PUT, which allow the introduction of 2 scale factors, compensation of the earth rotation effect, histogram analysis and manipulation, as well as output on a line printer recording 13 gray levels.

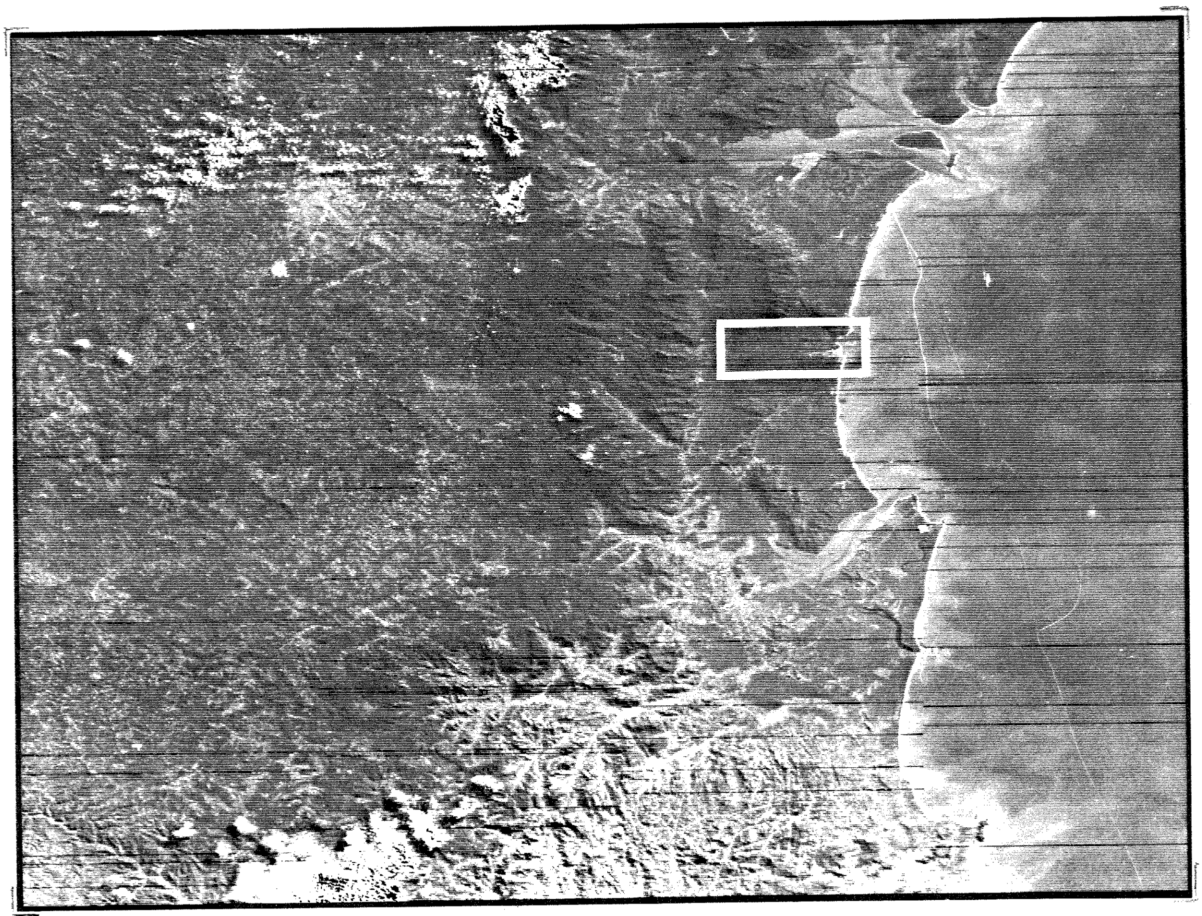

Fig. 2: LANDSAT scene at Brazilian Atlantic coast, south of Paranaguá (25,5^{o}S), channel 5
Acquisition date: July 15th, 1976
Test site Guaratuba

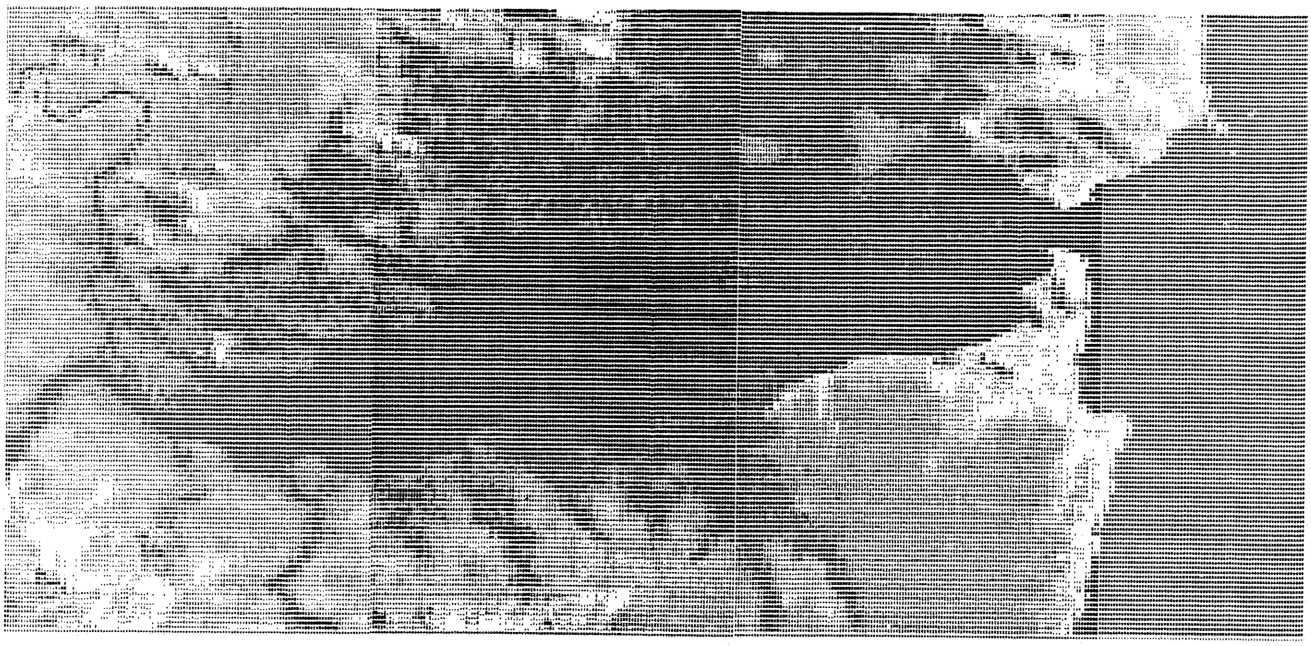

Fig. 3: Alphanumerical output of test site, photographic reduction
to 1 : 130 000, enhanced version (band 7)

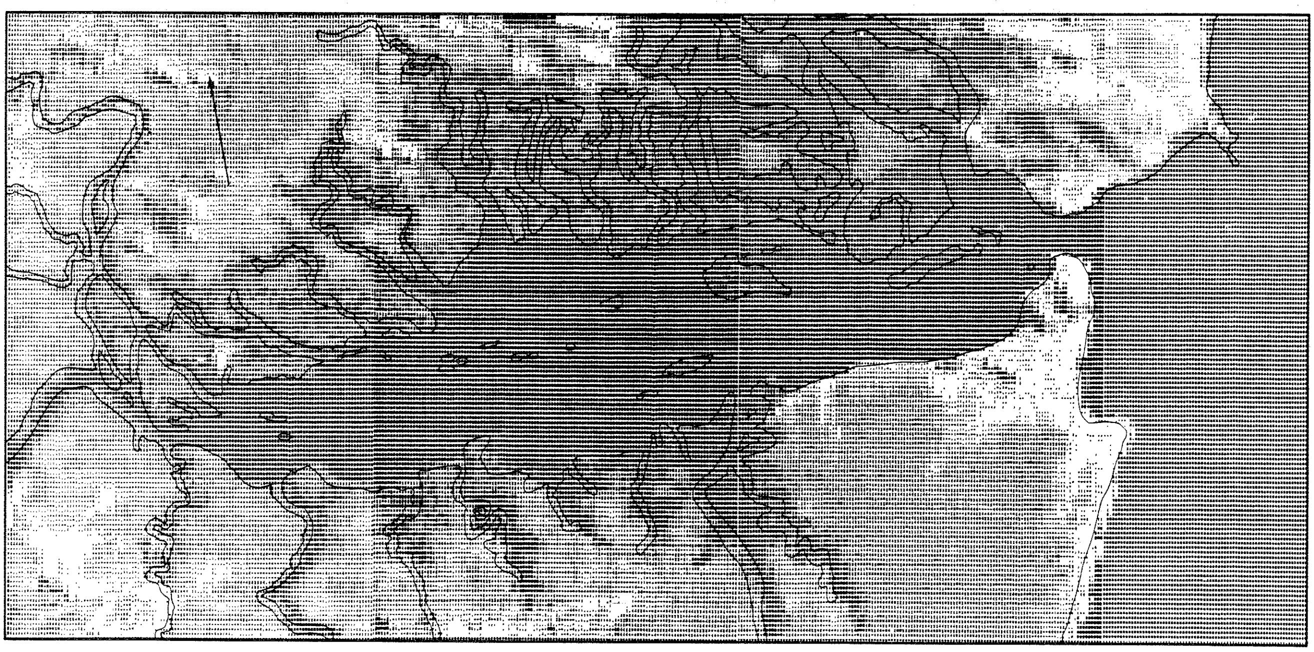

Fig. 4: Water line drawn from topographic map 1 : 50 000 compared with
alphanumerical output after processing by SPID - 1
Scale 1 : 130 000

4. Results

Fig. 2 shows the LANDSAT-scene which served for practical tests. It contains the raw CCT data, without geometric corrections applied (scanner output courtesy of Photogrammetric Institute in Hannover/FRG). The geometric deformation (by the affine factor 1,41) is clearly visible, as well as the misregistered lines, which appear at the time continously in two adjacent vertical data bands. The scene is located in the region of Curitiba and Paranaguá (northern part) and does nearly reach Florianópolis in the south. The marked small area near the coastline of about 11 km x 23 km is the test site for application of the SPID-1 program. In the original image no details are identifiable.

The alphanumerical print (Fig. 3) presents lots of details within the test site (Bay of Guaratuba); many tiny mangrove river branches are distinguishable. Comparison with the water line drawn directly from the topographic map 1 : 50 000 (Fig. 4) shows perfect fitting though only visually controlled.

5. Conclusions

To get started with digital image processing, it is generally not necessary to invest very much in the hardware sector, since the core of the whole necessary hardware is a digital computer of medium or large size, like it is available today in most places of the world. Software is the more important factor.As far as Third World countries are concerned,many problems found there are a real challenge for remote sensing applications, that means digital image processing and digital mapping, too. Even though feeling a big gap between the industrialized and the developing countries, it may after all not be the best way to simply install "black boxes" in the latter. In order to learn what digital image processing can offer and to achieve a certain autonomy in that field, it is self-evident that Third World countries, at least in scientific and academic institutions, should develop digital image processing (software) systems on their own. The European countries did so, anyway, 10 years ago.Even when starting with "poor man's digital image processing" (after MULDER and DONKER), the advantages when understanding profoundly this technique, will at the long run be invaluable.

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