Determination of Control Points Using Hanning-Posson Filtering and Satellite Image Rectification Using a Bidimensional Approach with Separate Variables

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ABSTRACT

A remotely sensed image presents several radiometric and geometric distorsion which are due essentially to attitude variations of satellite around its orbit and to the rotation and curve of the earth.
The geometric rectification of satellite image is an essential step for the exploitation of the remotely sensed data. It can be carried out by using a model of deformation based on a research of the homolog points between an image and its reference.
The determination of control points on a digital image is a difficult operation. In fact, a control point is not constituted by only one pixel but by a group of pixels. The questions is:
Which pixels could one choose among the group of these ones?
We propose, in this paper, a solution which involves the image filtering through Hanning-Poisson filter.
Otherwise, the image geometric rectification has been carried out by the dimensional approach with separate variables allowing a parallel processing and a better organization of data. Tests have been realized on SPOT/XS image with resampling filters.

INTRODUCTION

The geometric rectification of satellite images is an essential step for the exploitation of the remotely sensed data. It can be carried out by using a model of deformation based on a research of the homolog points between an image and its reference.
A cartographic reference is constituted by a group of topographic elements such as railways, road cross, sea sides and so on. Hence the using of the edge detection of the image in order to emphaze these features.
This detection gives boundaries which have not surely a pixel size (Fig. 1), hence the necessity to do a local filtering of the image with the help of Hanning-Poisson filter whose the frequential response presents a very special central top.
If we consider the consider the following where would like to determine a control point coordinates representated by a group of pixels. (Fig.1)

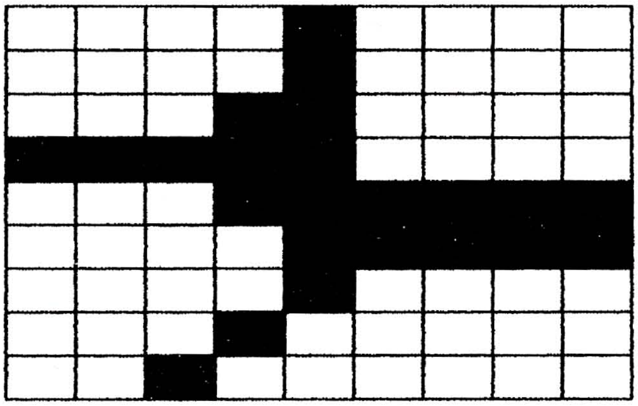

Fig. 1.a - Representation of a Control Point.

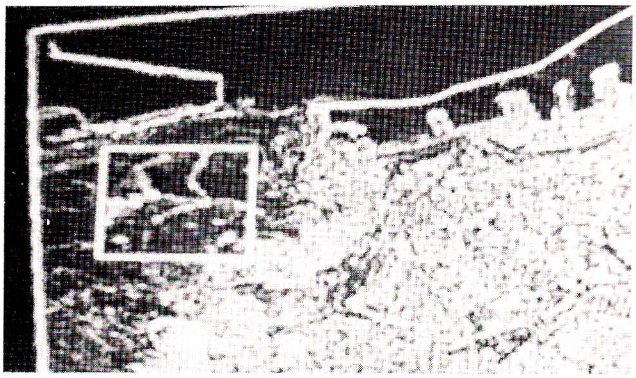

Fig. 1.b - Example of a zoomed candidate Control Point.

That is to determine the pixel coordinates among this group of pixels in order to representate a control point. For this, we use a Hanning-Poisson filter.
The used procedure consists on sweeping a neighbouring of the group of pixels by Hanning-Poisson filter. The maximum value allows the extraction of the pixel coordinates (control point).

1. A HANNING-POISSON FILTER

The unidimensional expression of the Hanning-Poisson is as follows [Harris, 1978]:

$$w\,(t) = 0.5\left(1.0 + \cos\left(\pi\,\frac{t}{T/2}\right)\right)\exp\left(-\alpha\,\frac{|t|}{T/2}\right) \quad (1)$$

where:

T: The window width
α: Damping coefficient.

The sampled expression of this filter can be written:

$$w\,(k) = 0.5\left(1.0 + \cos\left(\pi\,\frac{k}{N/2}\right)\right)\exp\left(-\alpha\,\frac{|k|}{N/2}\right) \quad (2)$$

where N is the number of samples and $0 \leq |k| \leq N/2$

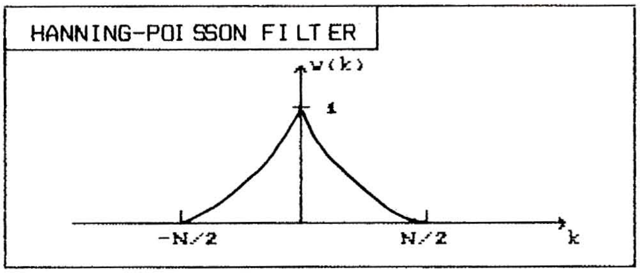

Fig. 2 - Representation of Hanning-Poisson filter.

The bidimensional expression can be written [Dan, Dudgeon & Russell, Mersereau, 1984]:

$$w(k,\,l)=w(k) * w(l) \quad (3.a)$$

D.E. Dugeon and R.M. Merserreau [Dan, Dudgeon & Russell, Mersereau, 1984] have shown that we can write:

$$w(k,\,l) = w(k)\cdot w(l) \quad (3.b)$$

$$w\,(k\,,\,l) = \left[0.5\left(1.0+\cos\left(\pi\,\frac{k}{NL/2}\right)\right)\exp\left(-\alpha\,\frac{|k|}{NL/2}\right)\right.$$
$$\left.0.5\left(1.0+\cos\left(\pi\,\frac{l}{NC/2}\right)\right)\exp\left(-\alpha\,\frac{|l|}{NC/2}\right)\right] \quad (4)$$

$0 \leq |k| \leq NL/2$
$0 \leq |l| \leq NC/2$

where:
NL: Number of lines.
NC: Number of raws.

2. DETERMINATION OF A CONTROL POINT COORDINATES

The control point determination on the image can be carried out by the following organigram:

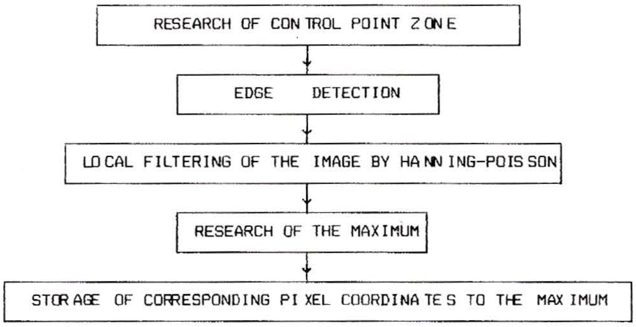

Fig. 3 - Organigramm of a control points determination.

Remarks:

1/ The first step consists in the visual determination of a control point.
2/ The edge detection is made locally.
3/ The Hanning-Poisson filter presents a symetry according to the origin (Fig.2). Hence the interest to calculate it only on the half on the window.

3. IMAGE RECTIFICATION

The group of these control points allows a modelisation of deformation with a polynom [Richars, 1986] [Davison, 1986] which can be written as follows:

1° / direct model

$$\eta = \sum_{i=0}^{p} \sum_{j=0}^{p-i} a_{ij} x^i y^j \quad ; \quad \xi = \sum_{i=0}^{p} \sum_{j=0}^{p-i} b_{ij} x^i y \qquad (7)$$

2° / inverse model

$$x = \sum_{i=0}^{p} \sum_{j=0}^{p-i} a'_{ij}\, \eta^i \xi^j \quad ; \quad y = \sum_{i=0}^{p} \sum_{j=0}^{p-i} b'_{ij}\, \eta^i \xi^j \qquad (8)$$

where:

(x, y): Distorted image coordinates
(η, ζ): Corrected image coordinates
p : Interpolation order of the model.

Generally, the inverse model is used for the image rectification. The determination of the coefficients is made by quadratic errors minimisation.

The image rectification by the inverse model requires an important processing time and a considerable memory space. In order to reduce these two features, Yeng Shin Ren [Yang Shin-Ren, 1979] proposed a hardware implementation technique which consist in a bidimensional rectification with a separate variables. For our part, we propose in this paper a software option of this technique which consist to rectify the image following two directions x and y with reduction of processing time and memory space. The realization of this technique can be carried out as follows:

- Determination of the coefficients of the model (8)
- Image rectification following the direction y (Fig.4)
  For each $\eta = \eta_k$, we have:

$$y = \sum_{i=0}^{p} \sum_{j=0}^{p-i} b'_{ij}\, \eta^i \xi^j \overset{\eta=\eta_k}{\longrightarrow} y = \sum_{i=0}^{p} \left[\sum_{j=c}^{p-i} b'_{ji}\, \eta_k^j \right] \xi^i$$

We can set:

$$B'_k(i) = \sum_{i=0}^{p-i} b'_{ji}\, \eta_k^j \longrightarrow y = \sum_{i=0}^{p} B'_k(i)\, \xi^i$$

Image rectification following the direction x (Fig.5)
For each $\zeta = \zeta_k$, we have

$$x = \sum_{i=0}^{p} \sum_{j=0}^{p-i} a'_{ij}\, \eta^i \xi^j \overset{\xi=\xi_k}{\longrightarrow} x = \sum_{i=0}^{p} \left[\sum_{j=c}^{p-i} a'_{ji}\, \xi_k^j \right] \eta^i$$

We can set:

$$A'_k(i) = \sum_{i=0}^{p-i} b'_{ji}\, \eta_k^j \longrightarrow x = \sum_{i=0}^{p} A'_k(i)\, \eta^i$$

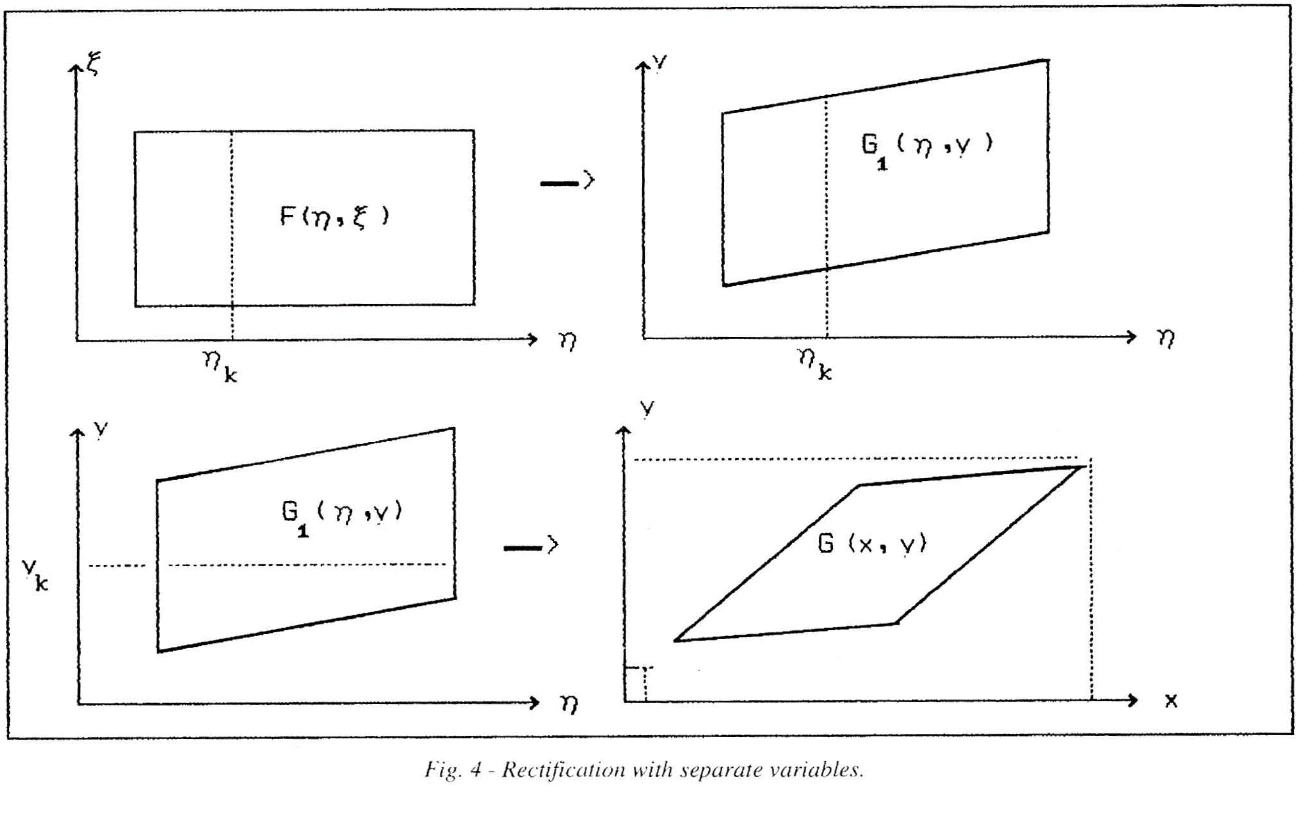

Fig. 4 - Rectification with separate variables.

3.1 Advantages of this technique

1/ A line k (respectively raw k) is independent of the lines (k-1) and (k+1) (respectively raws (k-1) and (k+1)). Hence the possibility of the parallel processing.
2/ A batch processing of lines (respectively raws) can be carried out according to the memory capacity of the computer.
The application of the inverse model creates real coordinates which do not correspond to entire coordinates of the pixels, hence the necessity of the image resampling. We have implemented the following filters:
- Nearest neighbour resampling [Richars, 1986].
- Bilinear interpolation [Richars, 1986].
- Cubic convolution interpolation [Richars, 1986] [Davison, 1986] [Bernstein, 1986].
- Mean [Nina Siu-Ngan Lam, 1983].
- Distance-Weighting [Nina Siu-Ngan Lam, 1983].
- Cubic Spline [Nina Siu-Ngan Lam, 1983].

4. EVALUATION AND CONCLUSIONS

These methods have been implemented on a workstation based on a IBM PC/AT compatible, with a video processor card of MATROX PIP 1024 A type and a 512x512 pixels display (pixel ratio:4/3).

The area of tests (Fig. 7) is situated in the west of Algeria (Town of Oran). This town is representative of the main themes of the landscape in this region such as:
- Forestry areas.
- Agricultural areas.
- Urban areas.
- Rivers and lakes (sekhas).

Two methods of control points determination have been used.
The first one is manual method using cursor and zoom on the graphic display. This method is necessary when we have to extract the point coordinates in an area where the details are very numerous.
The second one is the method of Hanning-Poisson filtering given by expression (2) where we can note that the filter selectivity increases with the α value.
For a good localisation of the control points, the value of the damping coefficient α has been chosen equal to 4. In fact, for the SPOT/XS images whose the ground resolution is 20 meters, the values of α greater than 4 give, perceptibility, the same results. An inferior values give a wrong detection of control points.

These two methods can be combined for the extraction of all necessary control points.
The manual method allows a better extraction of control points in an urban area, while the Hanning-Poisson method gives a better accuracy in forestry and agricultural areas with a weak urbanization.

CP no.	Ximage	Yimage	Xmap (m)	Ymap (m)	Residual X (m)	Residual Y (m)	Method
1	12.00	54.00	2775.00	2950.00	-2.58	9.78	H.P.F
2	82.00	74.00	4075.00	3600.00	6.14	-4.59	H.P.F
3	166.00	99.00	5625.00	4400.00	4.65	-13.25	M
4	212.00	59.00	6650.00	3775.00	-10.66	-3.30	M
5	394.00	73.00	10200.00	4700.00	0.60	-0.49	H.P.F
6	360.00	182.00	9150.00	6775.00	15.83	34.17	M
7	271.00	221.00	7250.00	7200.00	8.25	6.61	M
8	395.00	233.00	9625.00	7825.00	-13.34	-29.64	M
9	285.00	294.00	7225.00	8650.00	-24.44	-3.52	M
10	332.00	344.00	8000.00	9775.00	14.22	4.96	M
11	131.00	335.00	4100.00	8900.00	4.09	5.44	H.P.F
12	64.00	313.00	2875.00	8225.00	-2.76	-6.10	H.P.F

Standard error in X = 11.18m or 0.5 pixel
Standard error in Y = 14.18m or 0.7 pixel
H.P.F : HANNING-POISSON Filter : M : Manual Method

Fig. 5 - Control points used in image to map registration example.

The following table (Fig. 5) shows a control points extraction using both methods. According to the residual values, we note that the Hanning-Poisson filter offers a better accuracy of the control point localisation.

In this example nearest neighbour and cubic spline resampling were used in producing on a image 20 m grid by means of the pairs of the second order mapping polynomials. The results are shown in figures 6 to 11.

Fig. 6 - Map of test area.

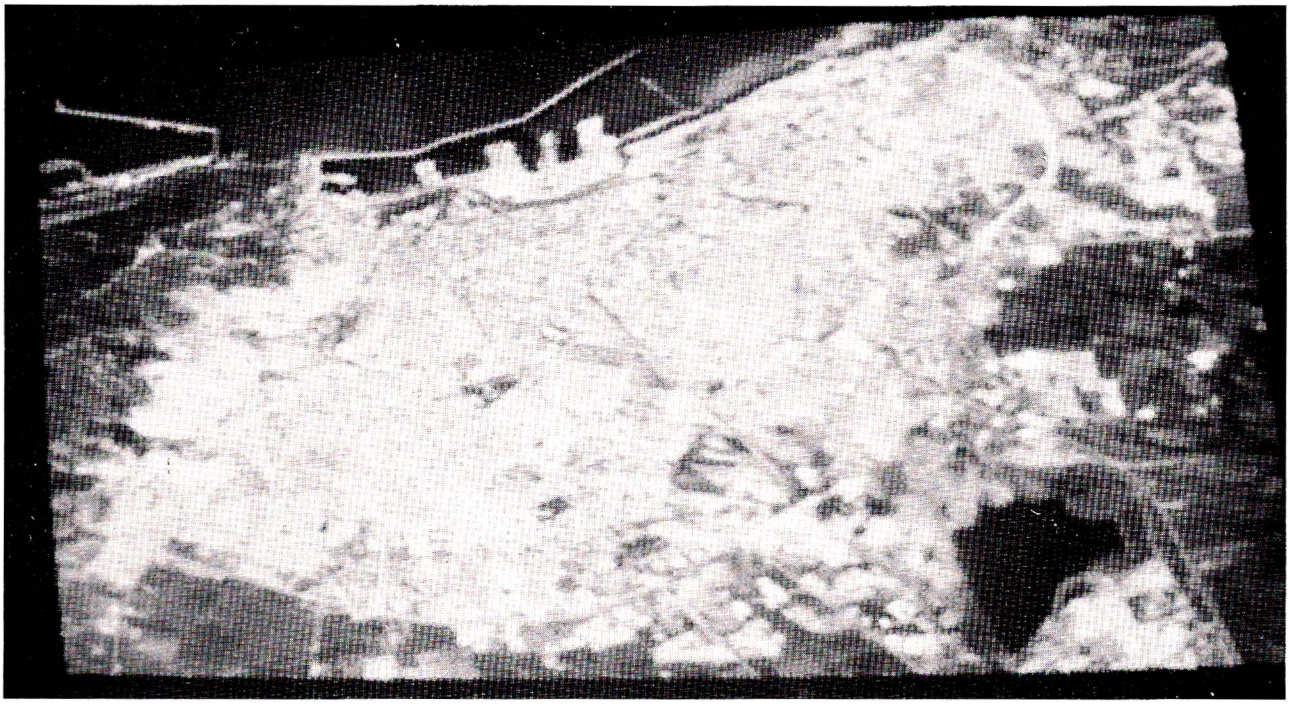

Fig. 7 - Original image.

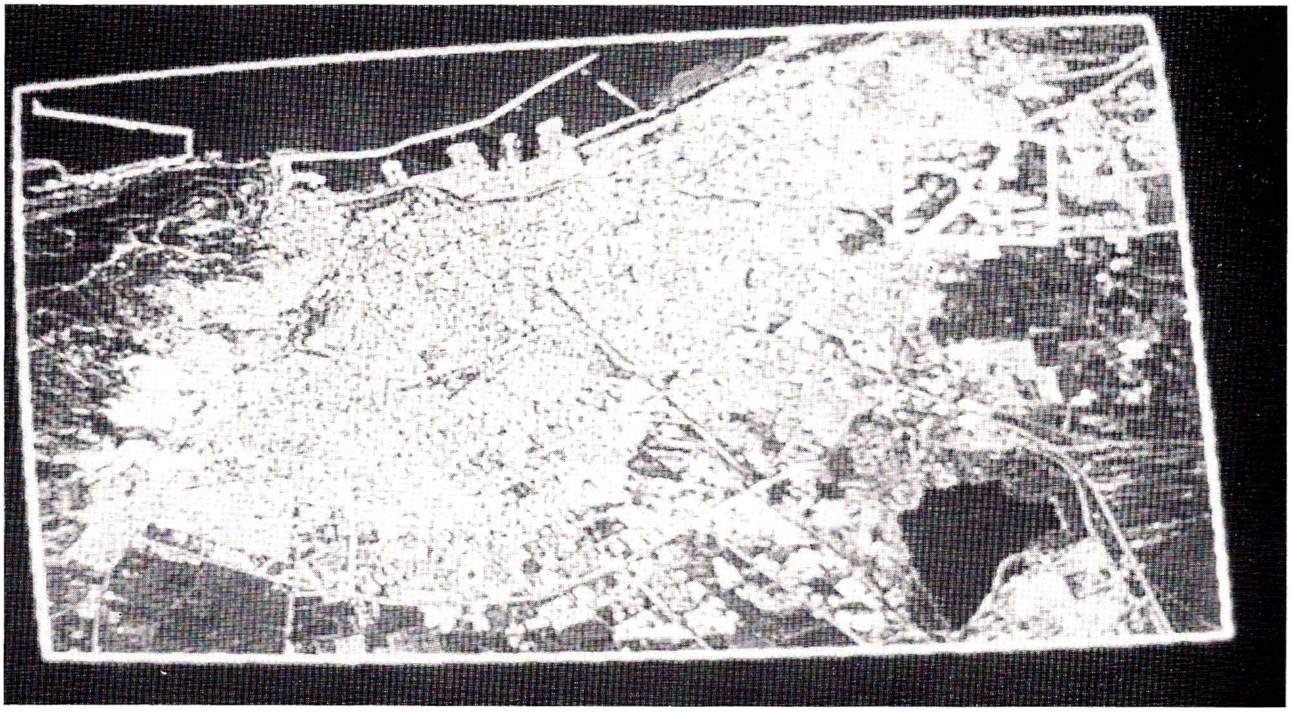

Fig. 8 - Edge detection (Modified Laplacian) of the original image.

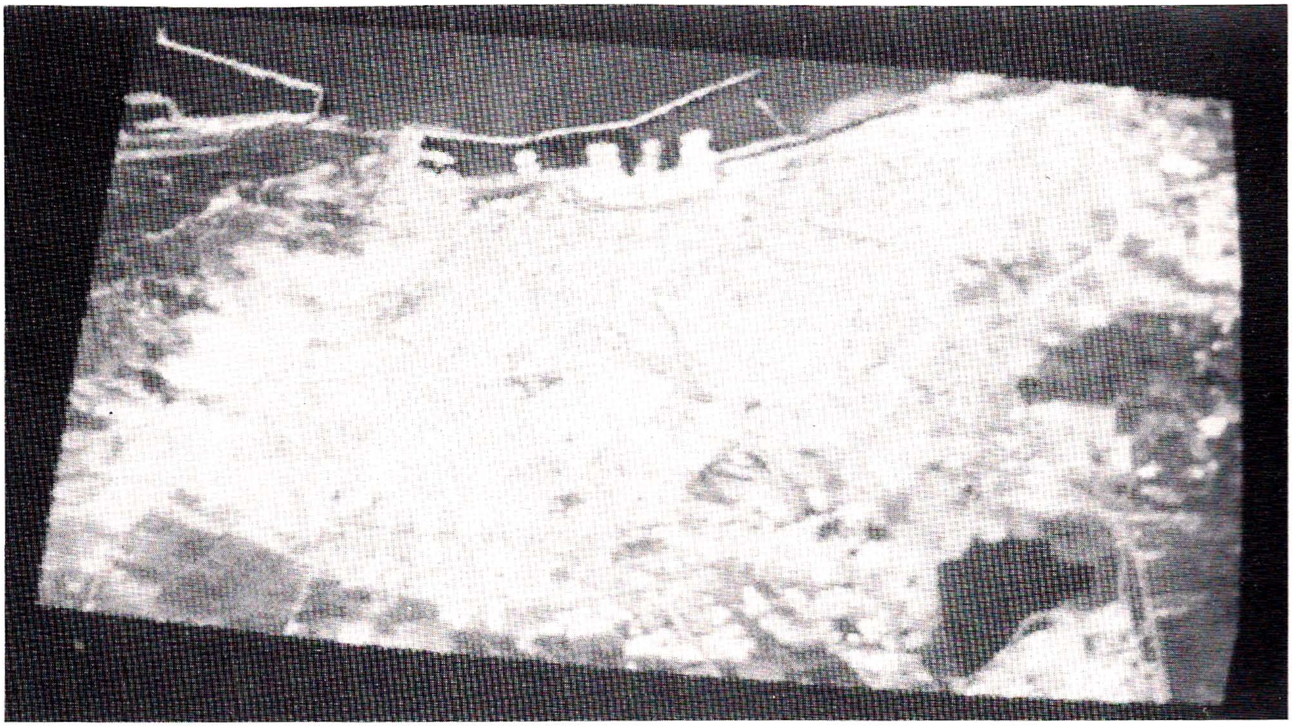

Fig. 9 - Rectified image with nearest neighbour resampling.

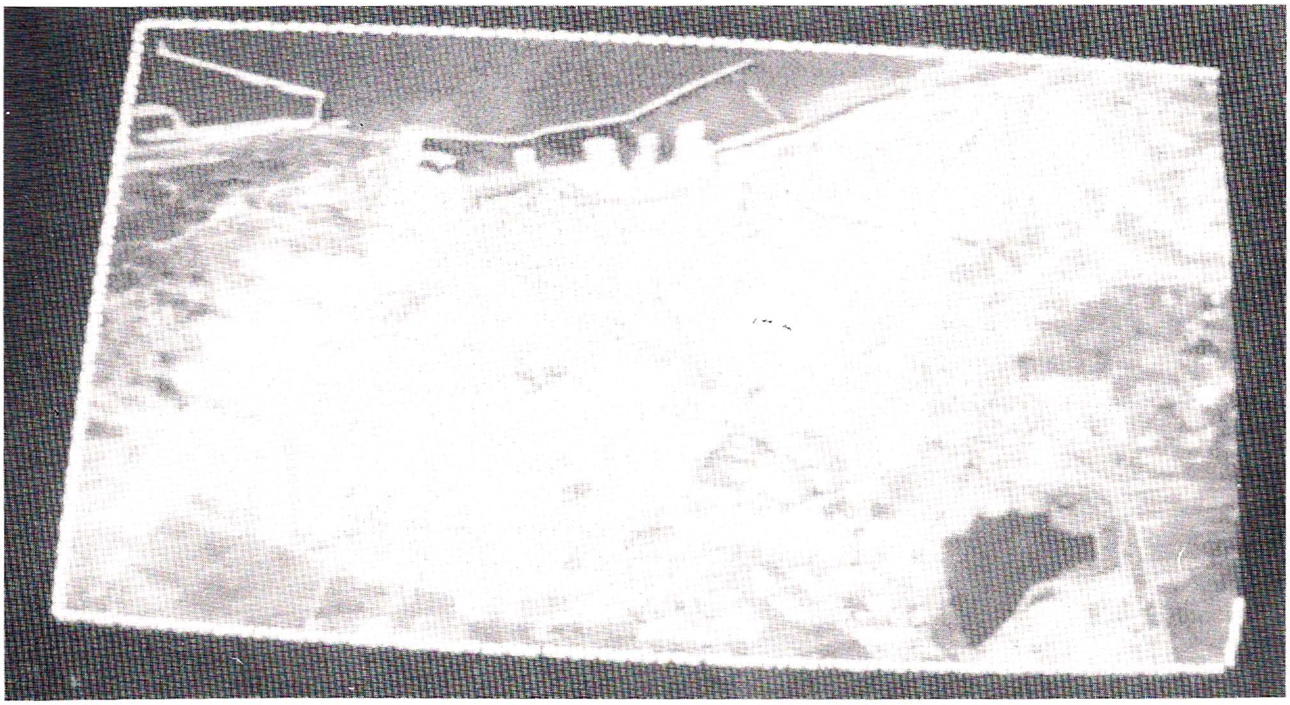

Fig. 10 - Rectified image with cubic spline resampling.

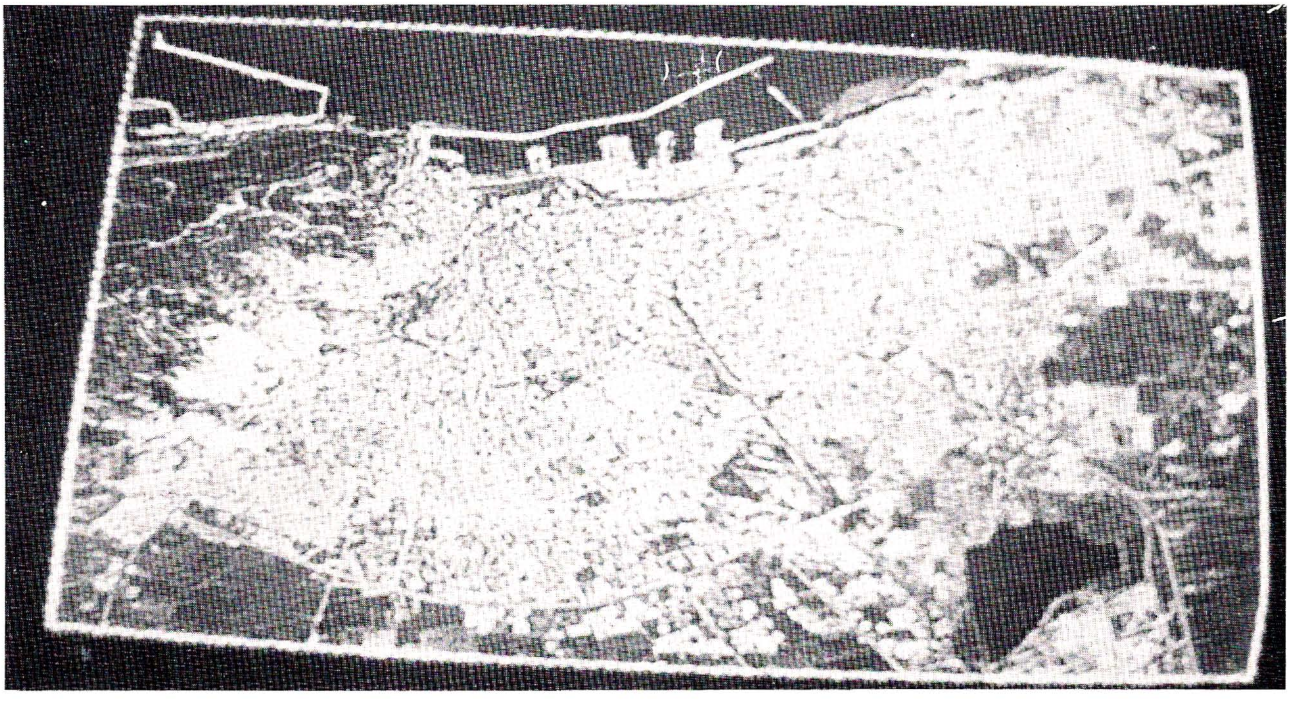

Fig. 11 - Edge detection of the rectified image with nearest neighbour resampling.

REFERENCES

Harris F.J., 1978, "On the Use of Windows for Harmonic Analysis with the Discrete Fourier Transform". Proceedings of the IEEE. Vol. 66, No 1, January 1978.

Dudgeon E., Merserau M., 1984, "Multidimensional Digital Signal Processing. Edition Prentice-Hall". New Jersey 1984.

Richards A.J., 1986, "Remote Sensing Digital Image Analysis. Centre for Remote Sensing and School of Electrical Engineering and Computer Science". pp.33-67, University of New South Wales, Kensington, Australia Edition Springer-Verlag, 1986.

Davison G.J., 1986, "Ground Control Pointing and Geometric Transformation of Satellite Imagery". International Journal of Remote Sensing. 1986, Vol. 7 No. 1.

Nina Siu-Ngam Lam, 1983, "Spatial Interpolation methods: a Review". The American Cartographer, Vol.10, No. 2, 1983.

Yang Shin-Ren, 1979, "Geometric transformation and data organization in digital image processing". pp. 157-177.

Niblack W., 1981, "The Control Point Library Building System". Photogrammetric Engineering and Remote Sensing. Vol. 47, N.12, December 1981, pp.1709-1715.

Edwards K., 1987, "Geometric Processing of Digital Images of the Planets Photogrammetric Engineering and Remote Sensing". Vol. 53, N.9, September 1987, pp.1219-1222.

Bernstein R., 1986, "Image Geometry and Rectification, Manuel of Remote Sensing".

Chibani Y., Alilat F., 1989, "Introduction à la rectification géomètrique de l'image SPOT". Rapport de stage, Institut d'electronique, U.S.T.H.B.