

TM LANDSAT IMAGE REFINEMENT USING STRAIGHT FEATURE AS CONTROL

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ABSTRACT

The main objective of this paper is to test and to assess the use of straight features as control in the refinement of TM Landsat images. Polynomial models and the model of the projective equation were adapted to straight features. The collection of actual data was done through maps in the 1:50.000 scale and through analogical TM image in the 1:1.000.000 scale. The best results were obtained for the second degree polynomial with RMS (Root Mean Square) = 35,76 m whereas the first grade polynomial showed RMS = 54,02 m. The results are very close to the "pixel" in the TM image (30 m) showing therefore the efficiency of the methodology.

Key Words: Algorithm, Landsat-TM, Straight Feature, Image Refinement, Control Points, Actual Data.

1. INTRODUCTION

1.1 Generalities

The remote sensing involves collection techniques and information processing, mainly about the Earth, by means of photographic or correlate processes. A great deal of information is offered to the user, which makes possible the creation of a consistent data base to the management of natural resources, e.g., soil use and occupation, mapping, among others. In order to attain such objectives, it is necessary that one understands the spatial, spectral, radiometric and temporal resolutions. (Forshaw, 1980).

The interrelations among spatial, spectral and radiometric resolutions are functions of the priority of a given specific application or of a group of applications.

When one searches the utilization of remote sensing for the monitoring of changes through the time, the temporal resolution becomes an important consideration to the determination of the characteristics of resolution of a sensing system.

The conventional procedure in cartography is the utilization of control points, relating the cartographic original to the real image. In the work with satellite images and with air photographs in small scale, the identification of control points is made difficult basically due to the spatial resolution of the image. With a smaller number of quality control points, in many cases the final product might be compromised. The use of features as control comes up as an alternative towards the minimization of this kind of difficulty, according to Masry (1981).

In the works of Image Refinement, the tests accomplished by Ford & Zanelli (1985) and Machado e Silva (1984a) and (1984b) were developed from satellite images of excellent quality, over exceptional areas, very much favored concerning control points, which made possible an almost uniform distribution over the image sector chosen.

In this work, the tests were performed over a TM Landsat Image that contains the City of Rio Claro, which is little favored as far as quality control points are concerned, and with lots of straight features.

1.2 Objectives

The main objective of this work is to evaluate the efficiency of the use of features in substitution of control points, when applied to the TM image refinement model of the Landsat 5 satellite, making use of actual data. The application was performed in a complete TM image scene, having in its interior a changing of zones of the UTM projection. This projection is the one which is adopted in the topographic maps which served as basis for the real image of the land to be known. In this work, a transformation of co-ordinates of the UTM system was performed, changing to an arbitrary local model where we performed the utilization of control points and straight features as a control for the image refinement tests.

1.3 Area of Study

The area of study is in the region of the State of São Paulo, whose geographic co-ordinates correspond to the latitudes $21^{\circ}00'S$ and $22^{\circ}30'S$ and to the longitudes $47^{\circ}00'W$ and $48^{\circ}30'W$ as it is showed in Figure 1.

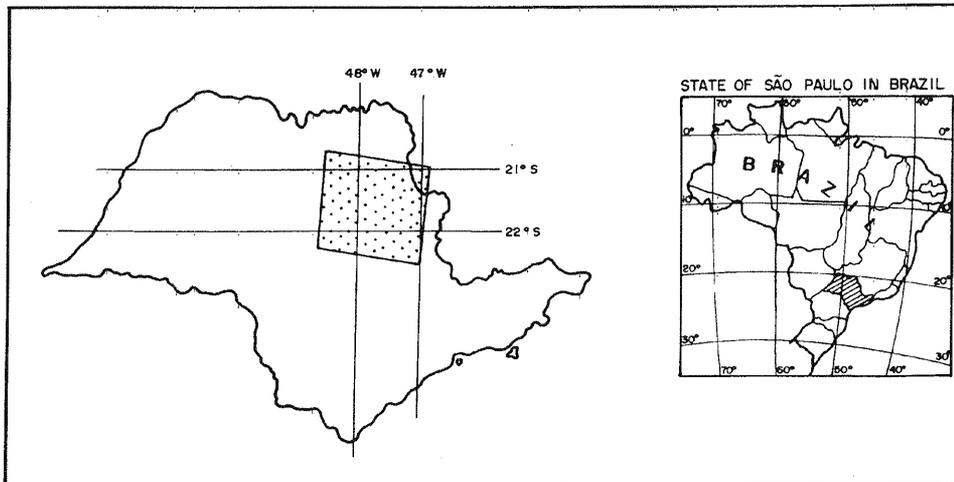


Figure. 1 - Localization of the area of study in the State of São Paulo.

This area is equivalent to the area covered by a Landsat image, approximately 185 x 185 Km, orbit 220, point 75 of the World Reference System (WRF). The 48° W longitude represents the changing of zones of the UTM projection. There are in this area points and features related to the zone whose central meridian is the one of 45° W, and others related to the zone whose central meridian is the one of 51° W.

2. IMPORTANT CONCEPTS

2.1 Image Refinement

The satellite images, when processed and after being corrected as far as radiometric distortions are concerned, go through geometrical corrections so that it can be applied to the mapping purposes, being it either thematic or topographic. The geometrical distortions can be classified as External or Internal distortions. The external distortions are the ones which come up from the dynamic behavior of the satellite, whereas the internal distortions come from the image making system itself. The items considered as sources of external distortion are the satellite orientation all along the scene, variation of speed and altitude of the satellite, rotation and sphericity of the Earth. As the main sources of internal distortions, there are the dragging of the image during a scanning, the non linearity of the mirror movement and the variation of the useful scanning time.

Among the models created to eliminate the effects brought about by these distortions, one can find the model that analyses each source of distortion separately, determining the correction to be applied to each point of the image (Machado e Silva, 1984a). Another model, called Photogrametric Model, is based on the equation of co-linearity and eliminates practically all the distortions which are present in the image. This model considers the distortions as being independent.

In the case of the images of the MSS sensor (Multispectral Scanner System) obtained from the Landsat Satellite, the Machado e Silva's tests (1984a), the most suitable model for this kind of refinement is the second degree polynomial model with $RMS = 60 \pm 15$ m. Bahr (1978) indicates the polynomial model as an alternative for refinement of geometrical correction.

The TM images (Thematic Mapper) are shown in five levels of Geometrical Correction, which will be approached here according to the image quality, according to Machado e Silva & D'Alge (1986), in the following way:

Level 0 : at this level a radiometric equalization and a re-sampling all along the lines are performed (Bezerra (1988)).

Level 1 : it is processed when there is no access to the ephemeris and altitude data transmitted by the satellite.

Level 2 : The co-linearity model is applied to two primary grades (28 x 18 break points) for which are known the ordinate pairs (line, column) and (latitude, longitude). The TM images at this level are the INPE's (INstituto de Pesquisas Espaciais), a Spatial Researches Institute, pattern product and show an RMS of 54 meters.

Level 3 : an image solicited at this level show an RMS of 50 meters.

Level 4 : the co-linearity model is applied to the grade of 386 x 18 "break - points", transforming after geodetic coordinates into plain-rectangular in the image system. $RMS = 47$ meters.

2.2 Straight Features as Control

Lugnani em (1984 a) defines feature as a term used to denominate an object or part of it, which may be represented by a segment of a spatial curve, as for example a road, a railway, the edge of a building, and so on.

When working with satellite images, the use of features becomes an important option if we consider that, in a small scale, the accurate identification of a portion of a road, for example, is much easier than the accurate identification of an intersection between a road and a river.

Besides what was explained above, another great advantage is that there is no necessity of a one by one correspondence between established points in the image and in the base map.

Some examples of successful applications of this alternative concept in Photogrammetry and Remote Sensing are the works of absolute analytical orientation of stereomodels Masry (1981) and Souza (1982); Analytical Resection of Photographies (Lugnani, 1980); the Digital Maps Review (Masry, 1981). The Projective Equation adapted to the features appears in the geometrical corrections of Skylab images in Lugnani (1980) and Freitas Viadana (1989).

Particularly in the works developed by Lugnani (1984b), (1980) and Freitas Viadana (1989), the results presented are equivalent to the one obtained by means of conventional control, thus confirming the potentiality of the use of features as control in the refinement of satellite images.

3. MATERIALS AND METHODS:

3.1 Materials

To the development of this work we used basically one microcomputer ITAUTEC - 286, one precision coordinatographer and one stereo comparator coupled to a coordimeter (Zeiss Jena); a TM image in positive transparency (scale 1:1.000.000) and 55 topographic maps from IBGE (scale 1:50.000) among others.

3.2 Data Collection

The data collection started with the collecting of the points and straight features which had matchings in the TM image. The control points used were, mostly, intersections of roads, intersections between roads and rivers (bridges), edges of airports, among others. The straight features adopted were principally portions of roads, paved or not, and airport which were from 600 m to 3000 m long.

The land co-ordinates (E,N) were obtained from topographic maps in the UTM projection through a precision coordinatographer of Zeiss Jena with a precision of 0.001" (one millesimal of an inch). From the average of four series of reading, we obtained for each point, one pair of co-ordinates (E,N) of the land, and for each feature we obtained the coordinate pairs (E_1, N_1) , (E_2, N_2) of the extreme point of each feature of interest.

To the determination of the images co-ordinates (x,y) of the points and straight features, we used TM images in positive transparency in the scale 1:1.000.000 and the stereo comparator "stecometer" also of Zeiss, operating as a monocomparator. This instrument features reading accuracy of the order of 0,002 mm. One series of four readings was performed for each point/feature of interest in the image. From the resulting average of the readings we obtained a pair of image co-ordinates (x,y) for each point or feature of interest.

It is important to note that the co-ordinates of the feature's image must belong to the straight line segment which is within the feature's extreme points of the feature, collected from the topographic map. Points chosen from out of these limits may lead to errors which impair the results.

3.3 Methods

3.3.1 Transformation of Co-ordinates

Aiming at the uniformization of the data collected from the IBGE, scale 1:50.000 in the UTM Projection System, which belong to different UTM zones, we decided on a transformation of co-ordinates from the UTM system to an arbitrary local system. All the work with tests of the mathematical models of TM image refinement, adapted to the straight features as control, takes place in the local system.

At the end of the adjustment, the refined co-ordinates are in the local system. Through the use of an Inverse Transformation, one has access to the final co-ordinates in the UTM Projection, from which the analysis and comparison of the results is performed.

3.3.2 Mathematical Models for the Tests with Image Refinement

Based on the results of the tests performed by Freitas Viadana (1989), where the methodology under discussion was applied to the polynomial model of first, second and third grades and the model of the projective equation was adapted to straight features for the refinement of a sector of TM Landsat images, we have chosen the tests which showed the best results.

Therefore, for this work which makes use of a complete scene, we have decided to test the first and second grade polynomial models and the model of the Projective Equation using control points also adapted to the use of straight features as control.

By using the straight line simplified equation in function of the co-ordinates of the extreme points (X_A, Y_A) e (X_B, Y_B) and of the straight line parameter (t) , one can now express the co-ordinates (x,y) of a random point:

$$X = X_A + t (X_B - X_A)$$

$$Y = Y_A + t (Y_B - Y_A)$$

Control Points

First Degree Polynomial Model

$$F_x \rightarrow a_0 + a_1 x + a_2 y = X$$

$$F_y \rightarrow b_0 + b_1 x + b_2 y = Y$$

Second Degree Polynomial Model

$$F_x \rightarrow a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 xy + a_5 y^2$$

$$F_y \rightarrow b_0 + b_1 x + b_2 y + b_3 x^2 + b_4 xy + b_5 y^2$$

Projective Equation Model

$$F_x \rightarrow (a_1 x + a_2 y + a_3) / (a_4 x + a_5 y + 1)$$

$$F_y \rightarrow (a_6 x + a_7 y + a_8) / (a_4 x + a_5 y + 1)$$

Straight Features as Control

First Degree Polynomial Model adapted to Straight Features

$$F_x \rightarrow a_0 + a_1 x + a_2 y - (X_A + t (X_B - X_A)) = 0$$

$$F_y \rightarrow b_0 + b_1 x + b_2 y - (Y_A + t (Y_B - Y_A)) = 0$$

Second Degree Polynomial Model adapted to Straight features

$$F_x \rightarrow a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 xy + a_5 y^2 - (X_A + t (X_B - X_A)) = 0$$

$$F_y \rightarrow b_0 + b_1 x + b_2 y + b_3 x^2 + b_4 xy + b_5 y^2 - (Y_A + t (Y_B - Y_A)) = 0$$

Projective Equation adapted to the Straight Features

$$F_x \rightarrow ((a_1 x + a_2 y + a_3) / (a_4 x + a_5 y + 1)) - (X_A + t (X_B - X_A)) = 0$$

$$F_y \rightarrow ((a_6 x + a_7 y + a_8) / (a_4 x + a_5 y + 1)) - (Y_A + t (Y_B - Y_A)) = 0$$

Where :

F : represents the function;

a_i and b_i , with $i = 1...8$ represent the transformation parameters;

(x,y) : represent image co-ordinates of the point/feature obtained from the monocomparator;

(X,Y) : represent the co-ordinates of the control point in the map;

(X_A, Y_A) and (X_B, Y_B) : represent the co-ordinates of the extreme points A and B of the straight feature in the maps respectively;

t = parameter of the straight line.

4. TESTS AND RESULTS

After the transformation of the co-ordinates of the UTM system into a local system, we proceeded the tests of the image refinement models, which already have uniformed co-ordinates of the points and of the straight features.

In this work, we tried to assess the results obtained for the work with points and straight features as control. It is necessary to point out that the tests were performed with a total of 16 points which were distributed among the control points and verification.

4.1 Tests Making use of Control Points

The results are shown by means of the Root Mean Square (RMS) that is given by:

$$RMS_x = ((\sum_{i=1}^{np} |X_A - X_G|) / np)^{1/2}$$

$$RMS_y = ((\sum_{i=1}^{np} |Y_A - Y_G|) / np)^{1/2}$$

$$RMS = (((RMS_x)^2 + (RMS_y)^2) / 2)^{1/2}$$

where:

np = total number of verification points for the test under discussion;

(X_A, Y_A) : values of the adjusted co-ordinates;

(X_G, Y_G) : values of the actual co-ordinates (GROUND Control).

To the control points, tests were performed for 7, 10, 12 and 14 points. It is necessary to point out that the tests were performed with a total of 16 points which were distributed among the control points and verification.

The verification and control points are distributed in the image according to what is shown in figure 2.

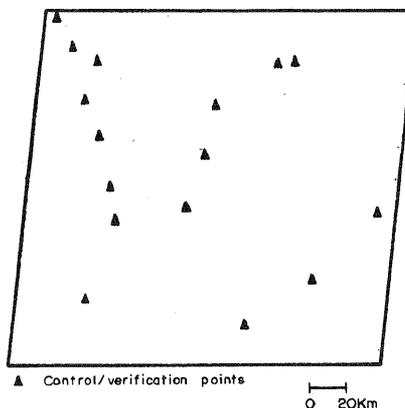


Figure 2 - Distribution of the 16 points in the image.

The Table 1 presents the results of the testes for the refinement test making use of control points.

4.2 Tests Making use of Straight Features as Control

In this case, we performed testes for 14 features as control, another one for 14 other features and for 20 straight features. As verification points, we used 14 points localized in the image.

The Figure 3 presents the distribution of the control features and the 13 verification points in the image. In this figure, the size of the straight feature was amplified.

The presentation of the results is given in a way analogous with the one given for the tests with control points.

The Table 2 presents the RMS for verification points in the testes with straight features as control.

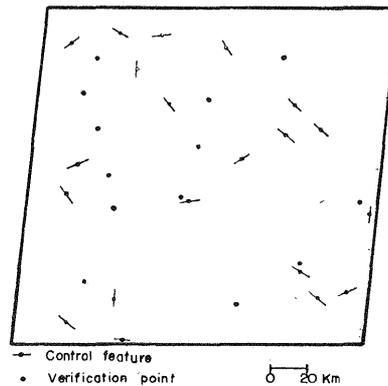


Figure 3- Distribution of the 25 control features and of 13 verification points in the image.

Table 1: RMS for the verification pointst for the tests with control points

"CONTROL POINTS IN IMAGE"		RMS (meters)		
NO CONTROL	NO VERIFICATION	1º DEGREE	2º DEGREE	PROJECTIVE EQ.
7	9	43,27	66,29	38,77
10	6	63,06	57,25	56,41
12	4	47,83	45,06	57,52
14	2	100,95	62,85	111,10

Table 2: RMS for the tests with straight features as control

"STRAIGHT FEATURES"		RMS (meters)		
NO CONTROL	NO VERIFICATION	1º DEGREE	2º DEGREE	PROJECTIVE EQ.
14	13	50,06	46,96	52,46
14 others	13	50,52	58,73	46,25
20	13	42,12	35,77	54,02

5. ANALYSIS OF THE RESULTS AND CONCLUSIONS

5.1 Control Points

Considering the existence of few control points identified in the image (16 points), whose distribution has not been ideal, which was done in a non homogeneous way the results may be considered satisfactory.

Although we have tried to evaluate the performance of the models by increasing the number of control points, this evaluation was impaired due to the non fixation of the verification points. This is already possible in the tests with features, where the verification points are the same for all the tests.

We have also observed that among the values shown in the Table 1, the best results were with the First Degree Polynomial Model (RMS = 43,268 m) and for the Projective Equation (RMS = 38.777 m) for the test with 7 control points.

If we consider that the TM Landsat image has a 30 meter resolution in the land, we can observe that the results are rather close to 1 pixel ("picture element"). The tests performed by Machado e Silva (1986) by the INPE reach an RMS of 50 meters.

The worst results were obtained for the tests with 14 control points, and this is probably due to the low quantity of verification points (2 points), which did not allow a more generic evaluation of the behavior of the model all along the image.

5.2 Straight Features as Control

If we observe the results shown in table 2, we can see that the best results obtained were for the test with 20 control features, for the second degree polynomial model (RMS = 35,765 m), followed by the first degree polynomial model (RMS = 42,124 m), both very close to 1 pixel (30 meters).

As a general rule, the RMS values showed quality, being in balance with the results obtained when control points were used.

5.3 Conclusions

As a first and important conclusion, we point out the noticeable improvement in the final results of the tests with models of TM image refinement of this work, when compared to the ones obtained by Freitas Viadana (1989), where the best results were around RMS = 52 m. This is because of the better distribution of points and features by the image, and mainly because of the increasing in the number of quality control points. In this way, the application of co-ordinates transformation, aiming at an unification of the land co-ordinates system brought about contributions to the tests with models of TM image refinement.

A second but not least conclusion is the confirmation of the quality of the results in the tests in which actual data were used. The features, appearing in a larger quantity than the points, make the data collection easier, even in regions provided with few conventional control points.

It is also important to point out that, generically, both the polynomial models of first and second degree, and the Projective Equation, proved to be efficient in the refinement tests. Therefore, it is difficult to choose the most efficient model for points and for straight features as control.

The RMS are, as it was mentioned before, very close to 1 pixel both in the tests with control points and in the tests with straight features, outdoing this way the results presented by the INPE, and consequently, the authors' initial expectation.

Besides, we used in this work one image dated 1986, and topographic maps based on air photographs dated 1965. This maximum difference of 21 years between the data has not affected the collecting of straight features as control.

A great number of features can be identified, which emphasizes the advantage of using features, even for a significant temporal difference among the data of the work.

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