APM Orthoretification with Satellite High Resolution Image

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Content

1. Introduction

Since the 1970's, one of the fundamental objectives for orbital images of remote sensing has been to improve spatial resolution. This resolution defines the larger scale that can be worked in an environmental application.

Nowadays, with high spatial resolution image with one meter or less, new applications with remote sensing images can be improved. In these cases, the surface topography has a big influence in geometric image distortions. So that to measure area, perimeter, distance, etc. in these images are necessary to apply a transformation called orthoretification to obtain a measurement with accuracy. This transformation was developed a long time ago for aerial photography, and today is necessary for digital images of remote sensing with high spatial resolution.

2. High Resolution Images

The IKONOS II satellite was launched in September 24, 1999, and has been working on since 2000. Images generated by the IKONOS II have 1 meter (panchromatic mode) and 4 meters (mutispectral mode). The radiometric resolution is defined by 11bits.

Basically, we have five options of IKONOS images, which are called GEO, Reference, Pro, Precision, and Precision Plus. GEO format is of low cost and will be utilized here. More details about IKONOS technical papers can be seen in space image, in the URL:

http://www.spaceimaging.com/techpapers/default.htm

QUICKBIRD II was launched in October 2001 and is operated by Digital Globe.

Images generated by QUICKBIRD II have the spatial resolution of 0.61 meters in nadir position and 0.72 meters (25° off-nadir) in panchromatic mode, and 2.44 meters (nadir) to 2.88 (25° off-nadir) in multispectral mode. More details about QUICKBIRD II technical information can be seen in the URL of Digital Globe's:

http://www.digitalglobe.com/about/quickbird.html

3. Affine Projection Model Equation

Authors like [1], [4] and [5] report that last years many mathematical models were developed to obtain three-dimensional spatial information and to generate orthoimages.

Mathematical models based on the colinearity equation need the data knowledge of sensor calibration, attitude and satellite orbit. With the GEO IKONOS format, for example, a mathematical model can be used to define the image position (x, y) and local geodesic referential position (X, Y, Z).

APM (Affine Projection Model) is based on an equation known as parallel projection, which projects space R3 on a R2 plane. With this modeling it is possible to transform R3 into R2 without knowledge of geometric parameters of sensor and satellite orbit. Points dislocation of relief are considered with the digital terrain modeling (DTM) of the test area [7].

Parallel projection is a particular case of central projection where the center of the projection is dislocated to infinity [6]. This kind of projection models the satellite system sensor of high resolution like push broom.

An IKONOS image, for example, is obtained by a linear sensor and has a high focal distance, and because of this it has a small angle of visible field. The geometry of a line of an image has a central perspective in cross track and can be approached by a parallel projection in the direction of the satellite's trajectory.

In [9] it can be observed that the projection model APM can be derived by using the conventional colinearity equation.

$$\begin{bmatrix} 0 \\ y \\ -c \end{bmatrix} = \lambda (R_{\phi j} R_{\omega j} R_{\kappa j})^T \begin{bmatrix} X - X_{0i} \\ Y - Y_{0i} \\ Z - Z_{0i} \end{bmatrix} \qquad (1)$$

Where (*X*, Y, Z) are coordinates of points on the ground of the site, λ is a scale parameter, *c* is the principal distance, $R_{\phi i} R_{\omega i} R_{\kappa i}$ are rotation matrices and (*x, y*) are coordinates of image point.

Supposing that an image is a parallel projection, the distance *c* can be considered in infinity and the equation (1) can be written as:

$$0 = a_{11}(X - X_{0i}) + a_{12}(Y - Y_{0i}) + a_{13}(Z - Z_{0i}) \quad (2)$$

$$Y = a_{21}(X - X_{0i}) + a_{22}(Y - Y_{0i}) + a_{23}(Z - Z_{0i}) \quad (3)$$

Where

a_{ij} (i = 1, 2, 3; j = 1, 2, 3) are matrix elements of $\lambda\,(R_{\phi i} R_{\omega i} R_{\kappa i})^T$.[9]

Supposing that the sensor moves in a linear manner in space and the parameters of orientation stay constant, the projection center of each line can be described as:

$$X_{0i} = X_0 + \Delta X_i \quad (4)$$

with X_0 and ΔX constant value and i the line number. A similar expression is defined for Y_{0i} and Z_{0i}. The line number i is obtained by putting eq. (4) in (2):

$$i = \frac{a_{11}(X - X_0) + a_{12}(Y - Y_0) + a_{13}(Z - Z_0)}{a_{11}\,\Delta X + a_{12}\Delta Y + a_{13}\,\Delta Z} \quad (5)$$

By substituting line i for the x-coordinate of the image, and considering the parameters of orientation as constants, eq. (5) can be written as:

$$x = \frac{a_{11}(X - X_0) + a_{12}(Y - Y_0) + a_{13}(Z - Z_0)}{a_{11}\,\Delta X + a_{12}\Delta Y + a_{13}\,\Delta Z} \quad (6)$$

Equation (6) is organized by constants coefficients and can be described by the following written expression:

$$x = A_1X + A_2Y + A_3Z + A_4 \quad (7)$$

The equation (3) can also be transformed through a similar arrangement, as:

$$y = A_5X + A_6Y + A_7Z + A_8 \quad (8)$$

Where,

(x, y) = plane coordinate in image referential

(X, Y, Z) = Tri-dimensional coordinates in local geodesic referential

(A_1, A_2 ..... A_8) = transformation parameters

Equations (7) are (8) are known as APM equations.

4. Orthoretification

Digital orthoretification improves the correction in the distortion of the image, especially the satellite position, physical position of earth (relief and curvature) and cartographic projection. To develop the image orthoretification it is necessary to know the DTM (Digital Terrain Model) [10]

The concept of generating an orthoimage from an image is very simple and can be obtained by differential rectification of the image (figure 1) and consists in mapping the gray value of the image for each cell of the DTM grid.

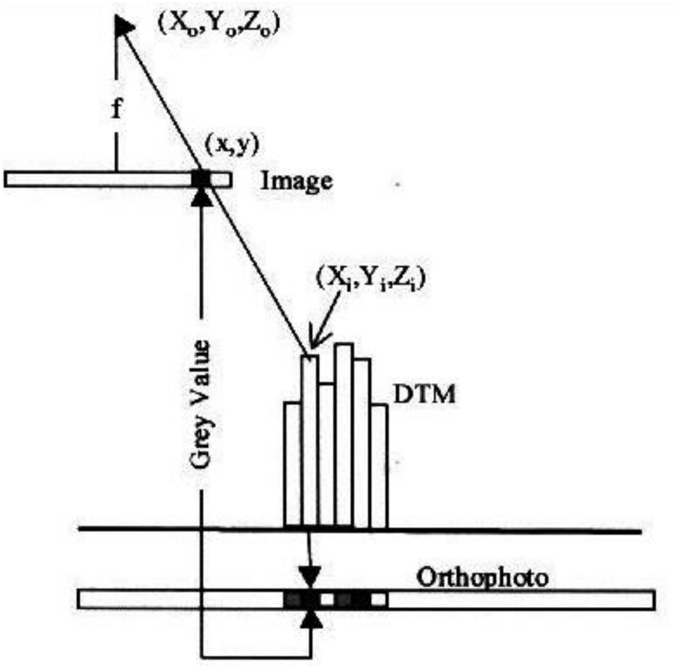

Figure 1 : Image Differential Rectification (Source: Novak & Sperry, 1992)

5. Study Area

A region of Curado in Recife-PE is our study area. An IKONOS and QUICKBIRD image of this area (1 km^2) was used to test the orthoretification. This area presents a relief of a maximum of 70 meters of altitude and has topographic information at 1:2000 scale. Figure 2 shows the *IKONOS GEO* image of the study area and Figure 3 shows the QUICKBIRD image used.

6. Materials and Methods

To carry out this research the following data was utilized: Plani-altimetric map in 1:2000 scale, UTM projection, Córrego Alegre Datum; recovering an area of 1.0 km^2, with E1=283000.000, N1=9105000.000, e E2=284000.000, N2=9106000.000, 33°W Central Meridian; *IKONOS* and *QUICKBIRD* images of the area test; Softwares *MatLab 6.0*, *Spring 4.0* and *ENVI* 3.5.

Figure 2 : *IKONOS GEO* image of study area

Figure 3 : *QUICKBIRD* image of study area

The methodology is described in a block diagram in Figure 4. GPS control points over a QUICKBIRD image is shown in Figure 5 (red points).

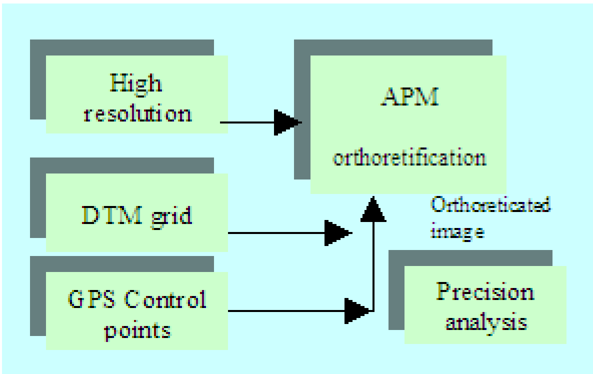

Figure 4 : Block diagram methodology.

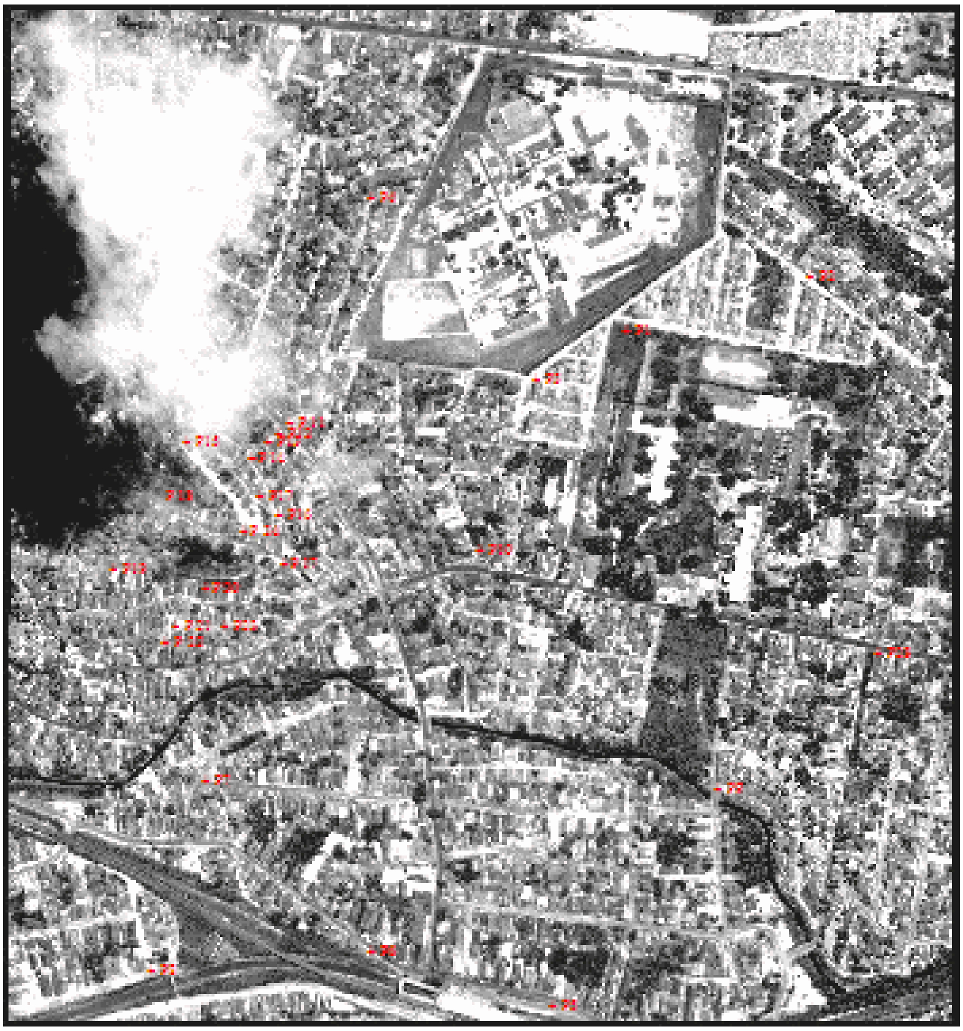

Figure 5 : QUICKBIRD image - GPS Control points

The control points are concentrated over higher places in the image. Topographic isolines in Figure 6 show the higher regions. Figure 7 shows the tri-dimensional region.

Table 1 shows coordinates (E, N) of control points with GPS (Global Position Satellite) obtained in the test area and are mapped in datum Córrego Alegre.

Table 1 : Coordinates (E, N) of control points

Control points	Coordinate UTM		Control points	Coordinate UTM	
	N (m)	E (m)		N (m)	E (m)
P001	9105841.2	283628.84	**P016**	9105703.3	283222.72
P002	9105897.7	283837.94	**P017**	9105664.7	283245.83
P003	9105791.6	283541.47	**P018**	9105627	283265.32

P004	9105989.1	283355.5	**P019**	9105651.7	283229.09
P005	9105079.9	283562.59	**P020**	9105546	283158.5
P006	9105146.8	283357.75	**P021**	9105537.2	283216.49
P007	9105338.4	283168.1	**P022**	9105574.5	283101.18
P008	9105127.6	283106.7	**P023**	9105580.3	283044.73
P009	9105329.4	283735.34	**P024**	9105705.9	283156.5
P010	9105468.7	283065.49	**P025**	9105694.3	283172.69
P011	9105310.8	283651.82	**P026**	9105672.7	283181.97
P012	9105590	283474.14	**P027**	9105692.7	283201.08
P013	9105737.3	283267.21	**P028**	9105651.7	283229.15
P014	9105724.8	283257.6	**P029**	9105589.3	283241.66
P015	9105714.1	283241.11	**P030**	9105666.2	283109.02

7. Results

The analysis of the result is based on [2] and [3] which describe the measurement of planimetric accuracy. The procedures to verify the systematic error and precision analysis are developed with the hypothesis test over the image and the terrain GPS points supposing the cartographic accuracy rule called (PEC - Padrão de Exatidão Cartográfica) in Portuguese, is based on Decreet n° 89.817/84 - Brazil.

Supposing that the final result is defined into the class A (most accurate cartographic mapping) of that law, the scale accepted to the ortoretificated image will be 1:10.000.

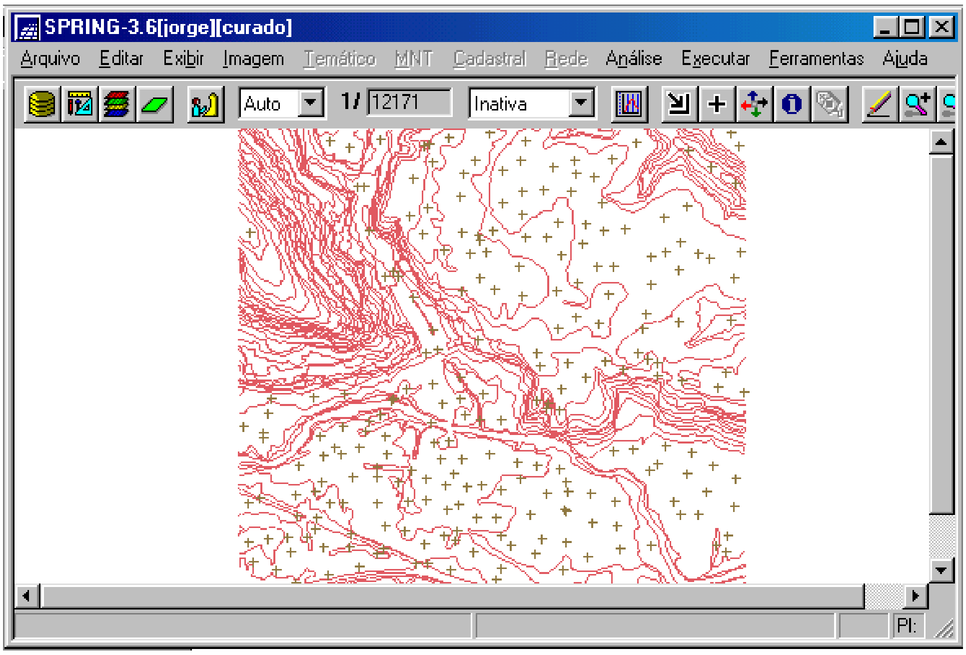

Figure 6 : Topographic Isolines in SPRING software

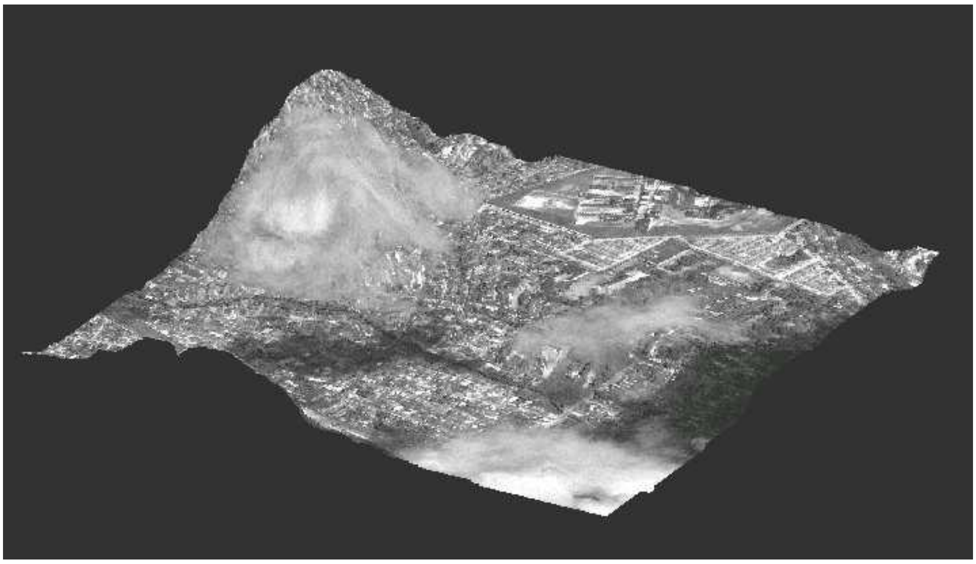

Figure 7 : Study area Image over DTM

Table 9 : Discrepancies between *GPS* and *QUICKBIRD* orthorretification

Control points	GPS coordinates		Image rectified coordinates		Discrepancies	
	N (m)	E (m)	N (m)	E (m)	ΔN (m)	ΔE (m)
P001	9105841.183	283628.844	9105841.855	283629.4458	-0.6716	-0.6018
P002	9105897.653	283837.944	9105897.326	283838.4875	0.3274	-0.5435
P003	9105791.562	283541.474	9105789.383	283542.4462	2.1792	-0.9722
P004	9105989.113	283355.503	9105989.357	283356.7027	-0.2439	-1.1997
P005	9105079.94	283562.594	9105081.335	283561.9355	-1.3945	0.6585
P006	9105146.801	283357.753	9105148.535	283356.3546	-1.7344	1.3984
P007	9105338.431	283168.103	9105338.993	283168.8837	-0.5621	-0.7807
P008	9105127.62	283106.702	9105127.843	283106.5846	-0.2234	0.1174
P009	9105329.431	283735.344	9105328.719	283735.0649	0.7122	0.2791
P010	9105468.741	283065.492	9105469.243	283065.9761	-0.502	-0.4841
P011	9105310.801	283651.824	9105311.461	283651.6407	-0.6598	0.1833
P012	9105589.962	283474.143	9105589.305	283474.1008	0.6566	0.0422
P013	9105737.282	283267.213	9105736.596	283269.5801	0.6862	-2.3671
P014	9105724.842	283257.603	9105724.716	283262.1196	0.1259	-4.5166
P015	9105714.052	283241.112	9105710.852	283245.2086	3.2004	-4.0966
P016	9105703.282	283222.722	9105697.668	283228.0501	5.614	-5.3281
P017	9105664.712	283245.832	9105661.413	283247.1885	3.2988	-1.3565
P018	9105626.962	283265.323	9105624.84	283268.9887	2.1219	-3.6657
P019	9105651.722	283229.092	9105647.611	283230.6899	4.1107	-1.5979
P020	9105546.041	283158.502	9105543.081	283160.9262	2.9603	-2.4242
P021	9105537.211	283216.492	9105535.616	283216.9754	1.5949	-0.4834
P022	9105574.522	283101.182	9105572.356	283101.8877	2.1658	-0.7057
P023	9105580.272	283044.732	9105577.418	283045.0912	2.8545	-0.3592
P024	9105705.922	283156.502	9105701.085	283157.4415	4.8372	-0.9395

P025	9105694.302	283172.692	9105688.116	283176.6771	6.1861	-3.9851
P026	9105672.712	283181.972	9105668.422	283183.8904	4.2897	-1.9184
P027	9105692.652	283201.082	9105692.919	283206.4923	-0.2672	-5.4103
P028	9105651.712	283229.153	9105647.768	283230.0559	3.9439	-0.9029
P029	9105589.252	283241.663	9105586.286	283241.1163	2.9663	0.5467
P030	9105666.202	283109.023	9105659.296	283113.1955	6.906	-4.1725
				Mean	1.849	-1.519
			Standard deviation		2.353	1.867

Table 10 : Results of Tendency Analysis

n		30
X_E		-1.519 m
X_N		1.849 m
S_E		1.867 m
S_N		2.353 m
$EP_{1:10.000}$		3.0 m
σ_x		2.12 m
$t_{29;\ 0.05}$		1.699
t_E		-3.924
t_N		5.010
analysis		$\lvert t_E \rvert > t$
		$\lvert t_N \rvert > t$
Components	E	has tendency
	N	has tendency

Table 11 : Result for precision analysis

$\chi^2_{29;10\%}$	**39.1**
S_E	1.662 m
S_N	1.939 m
$\sigma_{(1:10.000)}$	2.12 m
χ^2_E (Class A)	17.823
χ^2_N (Class A)	24.2595
Analysis	$\chi^2_{(Class\ A)} < \chi^2_{29;10\%}$
Scale used	1:10.000

8. Conclusion

This paper shows the APM equation to orthoretification images IKONOS and QUICKBIRD. The mapping rules in Brazil, based on PEC, were used to define the scale of the product. It was observed that both images (IKONOS GEO and QUICKBIRD) are good to use at maximum scale 1:10000 with this model of orthoretification.

The advantage of using orthoretification is the generation of images that are geometrically equivalents to the conventional planimetrics maps with the true orthographic position. With these images, cartographic updating and other applications can be used in GIS (Geographic Information System).

9. References

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