RPC MODEL FOR ORTHORECTIFYING VHRS IMAGE

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ABSTRACT: Three main important sources for establishing GIS are the orthomap in scale 1:5 000 with Ground Sampling Distance of 0,5m; DEM/DTM data with height error of ±1,0m and topographic map in scale 1: 10 000. The new era with Very High Resolution Satellite (VHRS) images as IKONOS, QuickBird, EROS, OrbView and other ones having Ground Sampling Distance (GSD) even lower than 1m has been in potential for producing orthomap in large scale 1:5 000, to update existing maps, to compile general-purpose or thematic maps and for GIS. The accuracy of orthomap generated from VHRS image affects strongly on GIS reliability. Nevertheless, orthomap accuracy taken from VHRS image is at first dependent on chosen sensor geometrical models.
This paper presents, at fist, theoretical basic of the Rational Polynomial Coefficient (RPC) model installed in the commercial ImageStation Systems, realized for orthorectifying VHRS images. The RPC model of VHRS image is a replacement camera mode that represents the indirect relation between terrain and its image acquired on the flight orbit. At the end of this paper the practical accuracies of IKONOS and QuickBird image orthorectified by RPC model on Canadian PCI Geomatica System have been presented. They are important indication for practical application of producing digital orthomaps.

KEYWORDS: Orthorectification, very high resolution satellite imagery, Ground Sampling Distance, Ground Control Points, Independent Control Points.

1. INTRODUCTION

In recent years the new era with Very High Resolution Satellite (VHRS) imageries as IKONOS, QuickBird, EROS, OrbView, has been in potential for producing orthomaps in scale 1:5 000- 1: 10 000 to update existing maps or to compile general-purpose or thematic maps (*Jacobsen, 2003*). VHRS Image not only has been widely used nowadays for military services but also for realization of various tasks of geodesy service and other commercial purpose as well. It is a very important information available to establish database of GIS. VHRS images are in particular suitable to investigate the climatic changes, natural risks such as a floods, earthquakes etc. The methods enable for the process of ortho-adjustment and mathematical relations describing geometrical imagery constitute extremely important tools, from the point of view of satellite photogrammetry, for practical application. The understanding of geometrical models of VHRS image is very important for improve orthorectification process. An overview about different models of VHRS image such as parametrical and Rational Polynomial Coefficient (RPC) model have been carried out to study at different research-scientific Centers in the World (*Grodecki et al., 2004; Luong and Wolniewicz, 2005, 2006; Michalis and Dowman, 2005; Tao et al., 2001*).

The purpose of a replacement camera model is to provide a simple, generic set of equations to accurately represent the ground to image relationship of the physical camera. A replacement camera model must not only model the ground-to-image relationship accurately, but must also perform the tasks normally performed with a physical camera model. In the sections that follow we will describe the RPC camera models of high resolution satellite that represented the indirect relation between terrain and its image acquired on the flight orbit (*Grodecki et al., 2004; Tao et al., 2001*).

The paper, at first, presents general mathematical relationship between ground and its image, describing with RPC model. Next, in the third section the characteristics of IKONOS, QuickBird imageries and test field of our experience have been presented. At the end of third section the results obtained from orthorectification process of IKONOS and QuickBird become analyzed and evaluated. The research results given in this paper are taken from our *Research Project* Nr 5 T12E 00724 (*Wolniewicz et al., 2005*).

2. BASIC OF RPC MODEL

The purpose of a replacement camera model is to provide a simple, generic set of equations to accurately represent the ground to image relationship of the physical camera. We might write that relationship as $(x, y) = \mathbf{F}(B, L, H)$ where $\mathbf{F}(.)$ is the replacement camera model function (x, y) is an image coordinates, and B, L, H is a ground coordinates (fig.1). Ideally, one set of equations, with different coefficient values, could model images from multiple camera designs. The Rational Polynomial Coefficients (RPC) of camera model of high-resolution satellite imagery is one of the very important replacement camera models that are quite often used in practice.

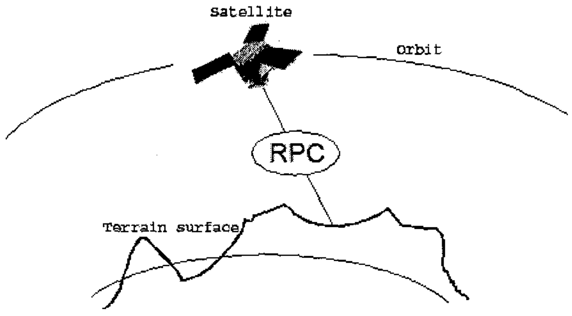

Fig. 1. RPC model of geometric relationship between imagery and Earth's surface

The RPC coefficients describe a single image from a particular imaging system. The RPC coefficients are used in the RPC equations to calculate an image (sample, line) coordinate from an object (longitude, latitude, height) coordinate. For this model, image vendors describe the location of image positions as a function of the object coordinates (longitude, latitude) by the ration of polynomials:

$$x_{ij} = \frac{F_{i1}(B,L,H)_j}{F_{i2}(B,L,H)_j}; \quad y_{ij} = \frac{F_{i3}(B,L,H)_j}{F_{i4}(B,L,H)_j} \quad (1)$$

where x_{ij} , y_{ij} - image coordinates; *B, L, H* - the latitude, longitude, height; and the polynomial F_i (.) has the following general form (3).

RPC express the normalized column *c* and row *r* values in an image, as a ratio of polynomials of the normalized geodetic latitude, longitude, and height (*B, L, H*). Normalized values are used intend of actual values in order to minimize numerical errors in the calculation. They are placed in the interval of [0, ±1].

$$\begin{aligned} B &= (Latitude - LAT\_OFF)/ LAT\_SCALE \\ L &= (Longitude - LONG\_OFF)/ LONG\_SCALE \\ H &= (Height - HEIGHT\_OFF)/HEIGHT\_SCALE \quad (2) \\ r &= (ROW - LINE\_OFF)/ LINE\_SCALE \\ c &= (Column - SAMPLE\_OFF)/SAMPLE\_SCALE \end{aligned}$$

Each polynomial $F_i(.)$ is up to third order in (*B, L, H*), having as many as 20 terms. For example, for a generic set of polynomial coefficient C, the corresponding 20-term cubic polynomial has the form:

$$\begin{aligned} F_i(B, L, H) &= C_1 + C_2L + C_3B + C_4H \\ &+C_5LB + C_6LH + C_7BH + C_8L^2 + C_9B^2 + \\ &C_{10}H^2 + C_{11}BLH + C_{12}L^3 + C_{13}LB^2 + \quad (3) \\ &C_{14}LH^2 + C_{15}L^2B + C_{16}B^3 + C_{17}BH^2 + \\ &C_{18}L^2H + C_{19}B^2H + C_{20}H^3 \end{aligned}$$

This is a third-order rational function with 20-term polynomials that transforms a point from the object space to the image space. Substituting $F_i(.)$ in Equation (1) with the polynomials in Equation (3) and eliminating the first coefficient in the denominator, we have a total of 39 coefficients in each equation: 20 coefficients in the numerator and 19 coefficients in the denominator. Since each GCP produces two equations, at least 39 GCPs are required to solve for the 78 coefficients.

3. EXPERIENCE PRESENTATION

3.1. Test field and image data

Two test fields „VAR" and "NOTAR" in Poland (*Wolniewicz et al., 2005*) belong to flat and mountainous ground surface, respectively. The test field VAR is a part of WARSAW city, has terrain undulation no lager than 80m. The test field NOTAR is a part of NOWY TARG district with terrain undulation up to 600m. For each test field „VAR" and "NOTAR" we have IKONOS and QuickBird scenes with their parameters presented in the table 1. Four parts of VHRS imageries of IKONOS and QuickBird of two test fields VAR and NOTAR are in the fig. 2.

For running orthorectification process of IKONOS and QuickBird the coefficients of RPC model have been delivered together with images by vendors.

Table 1: The parameters of VHRS imageries of the test fields „VAR" and "NOTAR"

Parameter	IKONOS- 2		QuickBird - 2	
	Test field VAR	**Test field NOTAR**	**Test field VAR**	**Test field NOTAR**
Number of scene	20030429095543 10000011310489	100317800000 111104058	1010010001 DE1101	1010001000 257FC01
Date of imaging	29-04-2003	17.06.2003	4-05-2003	03.10.2003
Time of imaging	9:55 GMT	10:03 GMT	9:35 GMT	9:22 GMT
Inclination angle of sensor axis	10,5°	14°	5,1133°	12°
Type of image	PAN/MS	PAN	PAN	PAN
Image product	Geo Ortho Kit	Geo Ortho Kit	Basic 1B	Basic 1B
Ground pixel size GSD	1,0m	1.0m	0,61m	0.64m
Image size	11,5km x 21km	11,5km x 9km	16km x 16km	16km x 16km
Percent of cloud	0%	0	2%	0

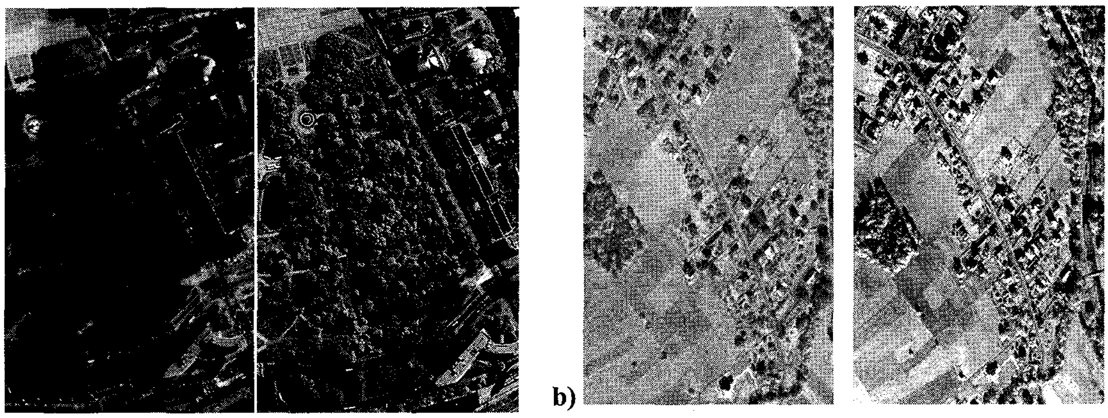

Fig. 2. Four parts of VHRS imageries: Test field VAR (a): IKONOS (left), QuickBird (right); Test field NOTAR (b): IKONOS (left), QuickBird (right)

For orthorectification process the DEMs of test fields VAR and NOTAR have been also applied. In this experience first DEMs of both test fields VAR and NOTAR was taken from DGPS set with height error of ±0,2m. Second DEM of test field NOTAR was taken with the spacing of square net of 30mx30m and the height error of ±3,87m.

3.2. Results and analysis

The software module ofRPC model installed in the **PCI Geomatica System** (Canada) for orthorectifying IKONOS and QuickBird imageries of two test fields VAR and NOTAR has been used. In the test fields VAR and NOTAR there are 17 and 27 Independent Control Points (ICP) used for analyzing the accuracies of orthorectification process, respectively.

Figures 3, 4, 5, present the Root Mean Square Errors (RMSE) of ICP position after orthorectifying by RPC model for IKONOS and QuickBird imageries. The abscissa axes on the figures present the number of Ground Control Points (GCP) used in orthorectifying.

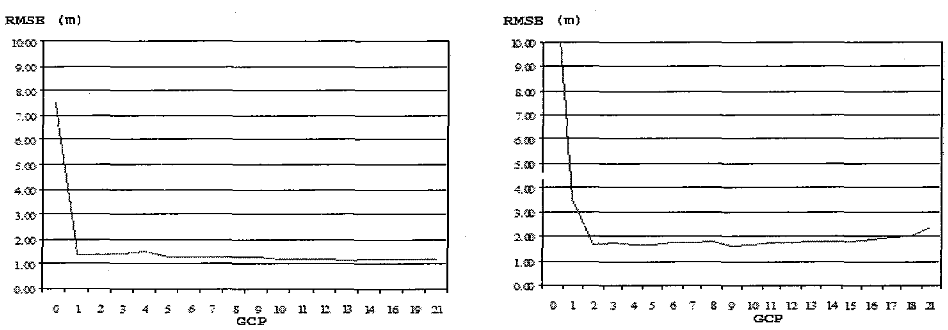

Fig. 3. Accuracy of IKONOS (left), QuickBird (right) orthorectified with RPC model for test field VAR using coordinates Z taken from DGPS

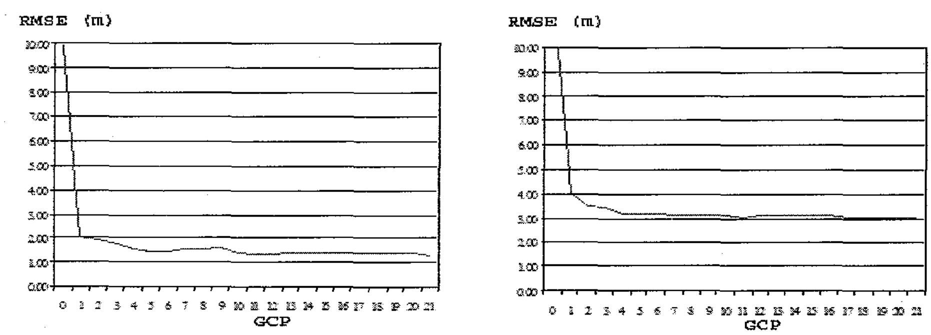

Fig. 4. Accuracy of IKONOS (left), QuickBird (right) orthorectified with RPC model for test field NOTAR using coordinates Z taken from DGPS

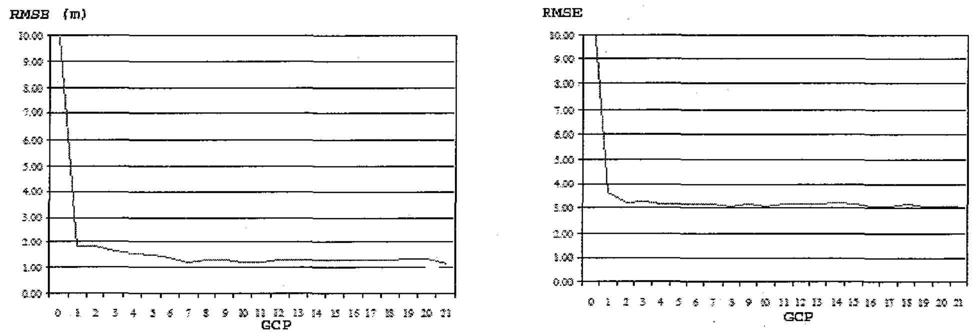

Fig. 5. Accuracy of IKONOS (left), QuickBird (right) orthorectified with RPC model for test field NOTAR using coordinates Z taken from DTM

From obtained results presented on the fig. 3, 4, 5, we can come to some conclusions:

- In order to receive the position errors in the interval of ±1,0m to ±1,5m for IKONOS imagery of both flat and mountainous terrain the number of GCP needed to orthorectifying by parametrical and RPC model is about 3 points.
- In orthorectification process of QuickBird imagery the RPC model is not effectively used even for flat terrain (with the position errors in the interval of ±1,5m to ±2,0m, see fig. 3), for mountainous terrain the position errors exceed ±3,0m (fig. 4, 5).
- The ground heights taken from DGPS and DTM used in orthorectification process of IKONOS and QuickBird imageries by RPC models have the same influences upon position errors.

4. CONCLUSION

The RPC model is generic, simple model that does not require the given data of imaging sensor and orbit elements. This model is effectively used for orthorectifying IKONOS imageries of both flat and mountainous terrain with available accuracies up to ±1,5m. Using the coefficients of RPC model supplied by image distributor the number of Ground Control Point, GCP, needed to orthorectifying is minimum 3. Basing on the experimental results we come to conclusion that IKONOS can be used to generate orthomap in the scale 1:8 000.

The RPC model can be used for QuickBird imagery of flat terrain with RMSE up to ±1,5m but not good for terrain with large undulation. According to our *Research Project*, QuickBird image can be useful to generate orthomap in scale 1:5000 when parametrical model is used for orthorectification process.

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