ASSESSMENT OF GEOMETRIC ACCURACY OF VHR SATELLITE IMAGES

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ABSTRACT:

VHR images of earths' surface are more frequently used and taken advantage of in substitution to aerial photographs. Geometric dependences of creation orthophoto based on aerial photos are known and distinguished from images of VHR. Results of work led are presented in this article within the confines of an investigative project under the Committee of Scientific Research of Poland concerning the geometric mechanism of VHR images and corrections. Two test fields have been made up for this project (city, country and mountain terrain). For those test fields, images from IKONOS, QuickBird were ordered. In the conducted research the angle of the axes was take into consideration: 0 ° – 15 ° In each test field area, after the identification of control points on the VHR images, about 30 – 90 GCP have been measured with GPS in accuracy of 10 cm. For image geometric corrections in this project two types of available DTM models in Poland have been applied with varying accuracy. Geometric correction have been realized with the aid of generally available software as PCI Geomatica 9 with taking into consideration RPC method and camera (rigorous) model. Throughout the work investigated, in each of the individual scenes of VHR various distribution and number of GCP was utilized for the process of orthorectification. Accuracy of orthorectification process received in result of led work, for VHR images at different configuration of geometry and methodology. Detailed results of experiments allow determining the optimal foundation for different methods of geometric corrections from IKONOS, QuickBird images and establishing effective process of dependence and defining geometric accuracy for different applications.

1. INTRODUCTION

In recent years we can observe rapidly increasing interest in the practical application of very high-resolution satellite imaging. The reasons are: from one side a need for satellite information about the surface of the earth to be applied in many different fields, and from the other side a need to achieve digital technologies optional to traditional photogrammetrical solutions (aerial photographs).
Poland is particularly interested in taking advantage of satellite imaging type VHR. This interest results mainly from an urgent need to cover the area of the country with such products as orthophotomaps, DEM or topographic database, in order to reach the same level of coverage as the countries of Western Europe. Therefore it is natural to see in VHR imaging a source of data quickly reaching this level of coverage. The project for creation of an orthophotomap of IKONOS images for an area of 50.000 sq kilometers, for the needs of LPIS (The Land Parcel Identification System programme was initiated in 1995 as an alphanumeric identification system for all agricultural parcels in EU) is the practical manifestation of such interest in VHR imaging. Also the Regional Operations Center (ROC) is situated in Poland. We are also considering the option of using QuickBird images.
In order to verify practical applications of such imaging, research was conducted, which comprised generating satellite orthophotomaps achieved with a use of many different techniques in various circumstances for the same land areas, obtained from the most commonly used VHR systems, i.e. IKONOS-2 and QuickBird-2.

The goal of this research was to compare procedures and technologies for producing orthophotomaps based upon the high-resolution satellite images for the selected testing area, which is the area of Warsaw, flat area, as well as Nowy Targ, an area of large de-leveling, foot-hills area. In the framework of investigations were provided accuracy evaluations of the achieved satellite orthophotomaps in different variants of geometrical correction. In this paper is presents detailed assessment of the planimetric accuracy of the panchromatic orthophoto from VHR images.

2. EXPERIMENT

The scenes achieved by the systems IKONOS and QuickBird for different time slots and angle deflections were used for the survey. For flat area (Warsaw) the deflection from axis in relation to nadir point are 5 degrees for QuickBird (DigitalGlobe provided a test image acquired over Warsaw, Poland) and 6.5 degrees for IKONOS. At the same time for mountain areas (Nowy Targ) they are respectively 9.5 degrees for QuickBird and 12 degrees for IKONOS (INTA SPACTURK provided a test image acquired over Nowy Targ, Poland). Precise characteristics of the imaging used have been presented in table no. 2.
In order to realize the process of ortho-adjustment, we presumed a photogrammetry matrix with the use of a GPS system. For determining coordinates of these points a TRIMBLE 4700 satellite dual-frequency receiver with Microcentere antenna was used. The survey was done with a use of

the fastatic method with an accuracy 0.1 m in the terrain for the values of x, y and z. During the survey, the terrain points were documented with photographs, on which the terrain situation and survey position were visible. They were used together with photographic sketches for pointing out the points on images (Figure 1and 2 .).

The process of determining coordinates future points to be used for correlation and for controlling mapping quality of the achieved points constituted a very important element. In each case we tried to ensure that the accuracy of GCP identification on the imagery was definitely below one pixel.

Imaging data	Type of imaging			
	QuickBird		Ikonos	
	Warsaw	Nowy Targ	Warsaw	Nowy Targ
Date of acquiring	04.05.2003	03.10.2003	07.06.2003	17.06.2003
Hour of imaging	9:35	9:22	10:01	10:03
Scene number	1010010001DE1101	101001000257FC01	100015550000011323057	100317800000111104058
Type of product	Basic 1B		Geo Ortho Kit	
Off nadir angle [degrees]	5	12	7	14
Radiometric resolution	11 bit		11 bit	
Field resolution [m]	0.61		1.0	
Scene size [km]	16 x 16	16 x 16	11 x 17	11 x 11

Table 1. Characteristics of imaging used

Figure 1. Projected identification GCP on QuickBird imaging fragment

Figure 2. Photo-point measured with a use of GPC identified in imaging

Thanks to the use of a GPS receiver for acquiring the points, all coordinates are of exactly the same accuracy of measurement, which considerably affects the result of adjustment. For ortho-adjustment we used two types of DEM: Digital Terrain Elevation DATA-Level 2 like accuracy type of grid 1x2” and height accuracy 5-7 meters, as well as grid 25x25 m and height accuracy 1-3 meters.

2.1 PROCESSING

Ortho-adjustment process were conducted using commercially available software: PCI Geomatica 9 including a module Ortho-Engine. This software enables the use of several methods of geometrical adjustment. In the framework of tests two methods were used:

Rational polynomial coefficient (RPC) method is the 3D model describing the relations land-image in form of polynomial quotient. “Firmware information” of mathematical relations in form of RPC coefficients is transferred within the image ordered. Terms of polynomial have no simple physical or geometrical interpretation connected with the parameters of camera of the image distortion factors, therefore it is called the "non-parametrical" model. These models take into account DEM height values for imaging terrain, and to a great extent they are free from the common disadvantages of polynomial coefficient transformations.

The Parametrical model (PM) describes actual relations between the land and its image, therefore the terms of this model have a precise geometrical interpretation. The basis for construction of the precise model for satellite imaging is the condition of co-linearity. In this point, however, it may be applied not to the entire image, but only to a single line. Parametrical models are less susceptible to photo-points distribution and possible errors in data. In the framework of research we used PCI software, taking into consideration the approach of doctor T. Touitn on parametrical relations for VHR type images. In the framework of survey conducted we presumed that the orthophotomap generated would be created in the "1992" Projection Gauss-Kruger; Spheroid: GRS80; Datum ETRS89 system, hence all auxiliary data for this process, namely GCP and DEM, had been previously transformed for this system. We also presumed that for accurate analysis of orthophotomaps created, only the VHR images in panchromatic range were used.

3. RESALTS AND ANALYSIS

We acquired orthophotomaps for images (QuickBird and IKONOS) with a use of the parametrical method (PM) (with use of a camera model) and the Rational Polynomial Coefficient (RPC) method, based upon PCI software. Uniform distribution of adjustment points for both methods was presumed. Figures 3-10 present a specification of acquired accuracy of generated orthophotoprocess. Each figure presents the achieved accuracy of ortho-adjustment for a given sensor and type of terrain depending on a number of GCP points. Achieved accuracy was checked on controlling points, which did not take part in the process of ortho-adjustment. In the framework of each scene we checked upon the accuracy achieved on controlling points (ICP) in number of some 20-30. These points were not used for adjustment process by possible support of DEM accuracy. In other words, for these points the value of Z for the process of correlation was not used. The figures presented show the following scenarios of orthorectification processes used:

- used values of Z in the process of ortho-adjustment on the basis of used points GCP from GPS survey,
- used values of Z in the process of ortho-adjustment on the basis of used points GCP "read only " from DTM.

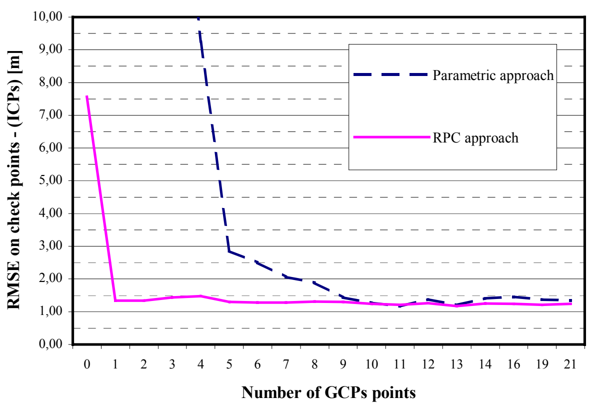

Figure 3. Accuracy of IKONOS for Warsaw area with "Z" values from GPS

Correction Method	RMS (m)		Maximum (m)	
	X	Y	X	Y
Parametric	0,96	0,84	1,77	2,02
RPC	0,89	0,86	2,00	2,40

Table 2. Comparison of RMS and maximum errors over 35 ICPs of parametric model and RPC computation with 10 GCPs

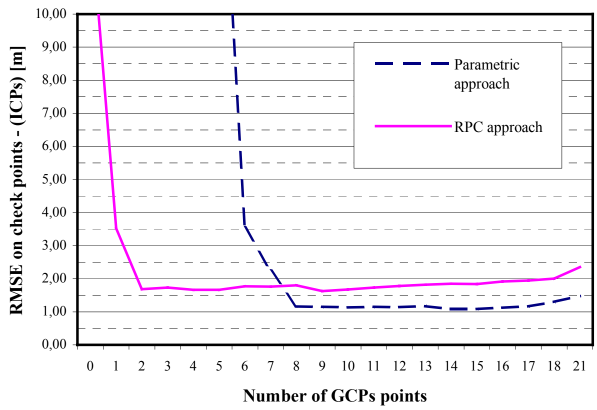

Figure 4. Accuracy of QuickBird for Warsaw area with "Z" values from GPS

Correction Method	RMS (m)		Maximum (m)	
	X	Y	X	Y
Parametric	0,94	0,64	2,25	1,44
RPC	1,31	1,05	3,93	1,94

Table 3. Comparison of RMS and maximum errors over 17 ICPs of parametric model and RPC computation with 10 GCPs

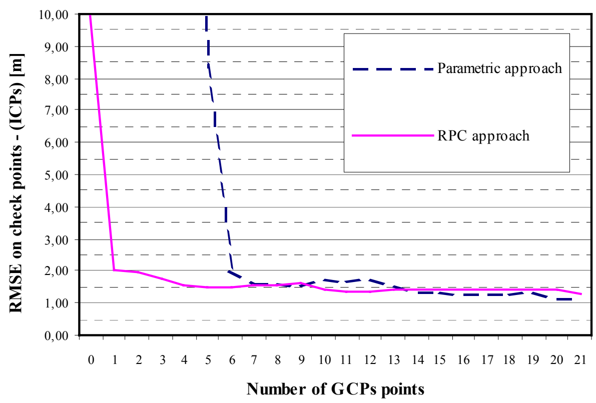

Figure 5. Accuracy of IKONOS for Nowy Targ area with "Z" values from GPS

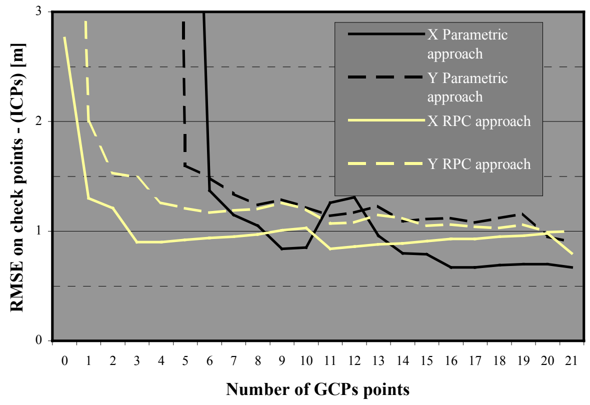

Figure 6. Accuracy of IKONOS for Nowy Targ

Correction Method	RMSE (m)		Maximum (m)	
	X	Y	X	Y
Parametric	0,85	1,22	1,62	3,23
RPC	1,03	1,20	2,92	2,05

Table 4. Comparison of RMS and maximum errors over 27 ICPs of parametric model and RPC computation with 10 GCPs

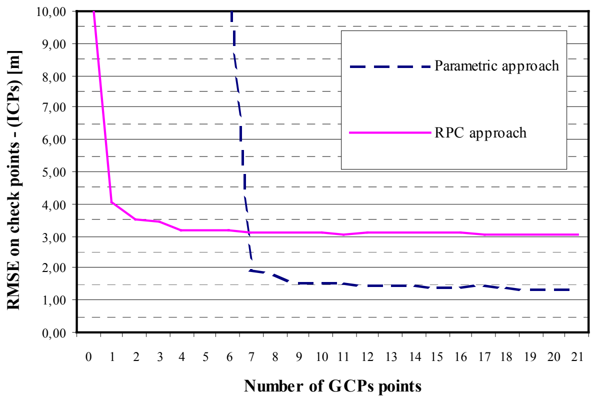

Figure 7. Accuracy of QuickBird for Nowy Targ area with "Z" values from GPS

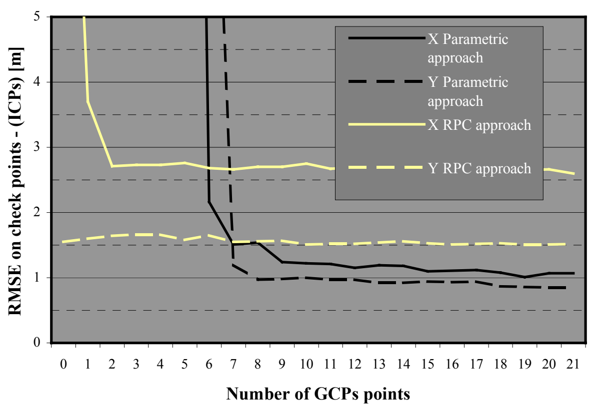

Figure 8. Accuracy of QuickBird for Nowy Targ

Correction Method	RMS (m)		Maximum (m)	
	X	Y	X	Y
Parametric	1,22	1,00	5,89	3,03
RPC	2,75	1,51	6,47	3,21

Table 5. Comparison of RMS and maximum errors over 91 ICPs of parametric model and RPC computation with 10 GCPs

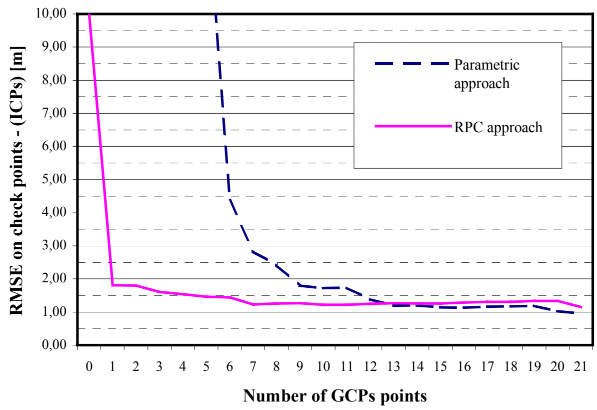

Figure 9. Accuracy of IKONOS for Nowy Targ area with "Z" values from DEM

Correction Method	RMS (m)		Maximum (m)	
	X	Y	X	Y
Parametric	1,44	0,95	2,94	2,09
RPC	0,90	0,83	2,90	2,68

Table 6. Comparison of RMS and maximum errors over 27 ICPs of parametric model and RPC computation with 10 GCPs

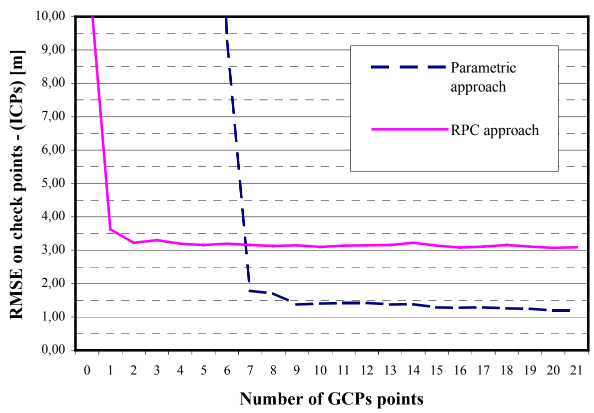

Figure 10. Accuracy of QuickBird for Nowy Targ area with "Z" values from DEM

Correction Method	RMS (m)		Maximum (m)	
	X	Y	X	Y
Parametric	1,05	1,94	3,45	6,08
RPC	2,70	1,52	5,84	3,14

Table 7. Comparison of RMS and maximum errors over 91 ICPs of parametric model and RPC computation with 10 GCPs

For row IKONOS data for Warsaw areas, a mean positioning error of 10 m in the Y (orbit direction) and only 2 m in X direction was found in the 35 ICPs.

1. For flat areas (Figure 3.), with a use of DEM of accuracy 5-7 meter (Z) and with a use of altimetrical points from GPS survey for IKONOS images, method RPC enables achieving accuracy (RMS) of some 1.5 meter irrespective of a number of GSP used. Even a use of a single 1 GSP provides for achieving sufficient accuracy. Parametrical method for this sensor requires a use of at least 9 GCP in order to achieve nearly the same accuracy.

2. In case of images achieved from QuickBird (Figure 4.) (for the same conditions), RPC method gives accuracy (RMS) of 2 meter, but with a use of minimum 2 GCP. Applying PM for 8 GCP we can obtain RMS nearly 1 meter.

3. For mountain areas (of de-leveling 500 meters) with identical DEM for IKONOS images, RPC method gives RMS of some 1.5 meter. With a use of PM, minimum number of GCP is 7, and it gives the same accuracy.

4. For QB imaging, using a method type RPC, we can obtain RMS slightly above 3 meters with a use of at least 2 GCP. At the same time, with a use of MP of minimum number of GCP equal to 9, we can improve the accuracy even twice.

4. CONCLUSION

Commercial PCI software used enables VHR ortho-adjustment with the use of methods RPC and PM for different numbers of GCP and available DTM, and to achieve accuracy in VHR ortho-adjustment process of nearly 1 meter. At the same time we have to be very strict when determining the following:

a. GCP points should be very precisely selected, measured and interpreted in the process of ortho-adjustment.

b. The test show that the parametric models demonstrating error stability for QuickBird orthorectification, with min. 8-10 of GCP. While non-parametric models is less precise for that system.

c. The parametric approach is very sensitive in accuracy for distribution GCPs in range of 7-10.

d. For IKONOS data non-parametric (RPC) approach has better stability and needs less GCPs points for orthorectification.

e. The input values of Z in the process of ortho-adjustment on the basis of used points GCP "read only " from DTM or GPS survey, it gives almost the same accuracy for ortho -rectification process.

f. For flat areas it is enough to apply DEM of accuracy in range 5-7 meters for IKONOS imaging with minimum number of GCP, achieving accuracy of some 1.5 meter. At the same time for QB imaging the application of parametric method brings better results.

g. Similar recommendations apply to mountain terrain. Using more precise DEM we can achieve a considerable improvement of accuracy.

h. The geometric limitation is the very often limited quality of control points in the images.

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