DETERMINE OF UTILIZATION RANGE OF RESURS DK-1 SATELLITE DATA IN THE FACE OF IKONOS SYSTEM

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ABSTRACT:

The results of investigations conducted within of the realization of research project funded by the Polish Ministry of Science and Higher Education were presented in the article. It was the main aim of the research project the accomplishment of the thorough review of the new Russian satellite data and the qualification their utilization range in the process of generating of the basic photogrammetric products. The methodology of geometrical correction and orthorectification of the source Resurs DK-1 panchromatic images on the basis of the metadata analysis was elaborated. The algorithms of the geometrical correction of the Resurs DK-1 image data which based on the correction modules valid for IKONOS and Quick Bird satellite data and functioning in photogrammetric commercial software Ortho Engine PCI Geomatica were the fundamental of this methodology. Two geometric correction variants were elaborated. In each variant the measurement of image coordinates of the control points as well as check points with use semi-automatically methods implemented in the Ortho Engine software was performed. In present article beside description of the methodology of geometrical correction of Resurs DK-1 satellite images the analysis relating to the influence of the accuracy of delimitation of external orientation Resurs DK-1 images on the accuracy location of the pixels in the orthoimage matrix were presented. It was affirmed that in orthorectification process for obtainment image map fulfilling of the accuracy criterion of the topographic map in 1:10,000 scale is required set of digital elevation points (DEM) with accuracy not worse than 4 m. The comparison of the satellite systems Resurs DK-1 and Ikonos-2 were presented in the article. Comparative analyses concerned to technical and economical aspects were referred to the orthorectification process. Taking into account all comparative factors it was affirmed, that the higher costs on the commercial market, approximate results and the time consuming of the photogrammetric study of scenes Ikonos in the relation to scenes Resurs DK-1 confirm the necessity to interest of new Russian satellite images.

1. INTRODUCTION

On the moment when on the commercial market appeared first very high resolution satellite images the Photogrammetry Department of the Institute of Geodesy and Cartography in Warsaw began complex methodical investigation aiming to the determine of their usefulness in the developing technologies of digital photogrammetric studies. It's concern to both single as well as stereoscopic scenes. In the aim of the determination of geometrical accuracy of these images the authors of the present article was analyzed the results of hitherto existing studies on the basis of acquired in this range experiences and was compared them with the results of photogrammetric studies of the blocks of aerial image made by the cameras with the registration of the perspective centers measured by the dGPS method. The source data used to this kind of analyses were mainly images of the Ikonos or Quick Bird satellite system. When in 2006 year appeared on the orbit Resurs DK-1 in the interest circle of the investigative team was foundling new Russian satellite system. In the same year in the Institute of Geodesy and Cartography was began the realization of the research project funded by the Ministry Science and Higher Education. The main aim of this project was the realization of complex methodical study to letting present for Polish scientists of the propriety of Resurs DK-1 satellite images in the face of growing requirements for present photogrammetric products. The elaboration of the methodology of geometrical correction and the methodology of orthoimage generating as well the comparison of accuracy of the Resurs DK-1 products with the accuracy products obtained from Ikonos images was the technological aim of this project. The got results of this study were one from first which were presented and published on the geodesic forum in the Poland.

2. NEW RUSSIAN SATELLITE SYSTEMS

2.1 Monitor-E

After the series of Resurs satellites the Russian space industry sought new sources of image data representing the standards of world technologies. Mainly this concerned on the change of the acquisition procedure of image information, and the same replacement traditional photosensitive materials by the optical sensors working in the wide range of the length of the electromagnetic wave. In 26th August 2005 on the sun synchronous orbit (altitude 535km) with inclination to the plane of the equator 87.8 º was began mission of the new remote sensing Russian satellite Monitor-E. The platform of the new satelitte has the ability to inclination off the nadir in range to 27º. The satellite was equipped in two electro-optical sensors Gamma-L and Gamma-C. The optical system of first from them described by the field of view 9 º was operated in panchromatic mode P (0.51-0.85 μm) with the geometrical resolution GSD = 8m. The image swath representing the optical proprieties of Gamma-L sensor was 90km with nominal range of viewing 780km. The image data was transmitted to the ground station with the rate of 122.8 Mb/s and recorded in

different formats with radiometric resolution 10 bit. The optical system of the Gamma-C sensor characterized by the field of view of 15.3 º allows realizing the images in multispectral bands in three ranges: M1 (0.54-0.59μm), M2 (0.63-0.68μm) and M3 (0.79-0.90μm) with the geometrical resolution GSD = 20m and with the image swath about 160km. The nominal range of viewing of the Gamma-C sensor was equal 890km by keeping of the radiometric resolution on the level 10 bit. At most one year later after the series of technical problems on the near-circular and elliptical orbit was appeared the newest generation Russian remote sensing satellite registered the image information with spatial resolution below 1m.

2.2 Resurs DK-1

The remote sensing satellite Resurs DK-1 was designed by RASA (Russian Aviation Space Agency) within of the realization of the National Space Programme of the Russian Federation. The main designer and producer of the satellite system Resurs DK-1 was the State Research & Production Space Rocket Center "TsSKB-Progress". Challenge for the new Russian satellite basing on the military recognition system was the task to entry in full tightly field of the performance of commercial remote sensing. The initial deadline of launch of the satellite Resurs DK-1 was happened on the December 2004. This deadline was moved on the April and later on the December 2005. However just on June 15th, 2006 was informed that at the 12 hour Moscow time the space craft Soyuz-U was placed on the orbit the satellite Resurs DK-1. Finally the satellite was placed on the elliptical orbit with inclination of 63º and elevation of apogee and perigee of 585km and 355km respectively. In the round of the day the Resurs DK-1 can to register images covered the surface area above 600 square kilometers. The exploitation time of the Resurs DK-1 was qualified on 3 years. The satellite platform have ability to incline off nadir maximally about 36º causing that revisit time of this satellite is 6 days. Acquisition of the image information by Resurs DK-1 sensors is realize in panchromatic mode in spectral range P (0.58-0.8 μm) as well as in multispectral mode in three bands M1 (0.5-0.6 μm), M2 (0.6-0.7 μm) and M3 (0.7-0.8 μm) with spectral resolution of 10bit. The geometrical resolution of the Resurs DK-1 image taken in perigee is 1m for panchromatic and 2-3m for multispectral mode. The Resurs DK-1 acquires satellite images in the swath width from 4.7km to 28.3km in the nominal scanning range of 448km. The main task of the Resurs DK-1 system is the observation of the surface of Earth, acquiring in the real time very high resolution satellite images in wide range of the electromagnetic spectrum and their processing and distribution to the customers in the world. The Resurs DK-1 satellite was entered on wide range of research and was performed ecological duty through delivering of information for operating action in the range of the expectation and the extermination of disasters and extraordinary situations.

3. ELABORATION OF THE RESURS DK-1 DATA

3.1 Description of the test data

In the methodical testing two panchromatic scenes with spatial resolution below 1 m were used. The geographic position of the scenes and their dimensions were adapted to requirements and possibilities which gives the realization of the research project. The first scene covered nearly of 12x12 km in the ground was represented the centre of the Warsaw and neighboring districts. This scene taken on September 24th, 2006 from the Geoton RDK-1 camera with an inclination of 6.35º and scan azimuth angle of 31.45º was used. The second scene covering about 10x10km in the ground represented the north-west districts of the Cracow was acquired in July 3rd, 2006 from the same camera like first test scene. The sensor inclination off nadir of 7.65º and scan azimuth angle of 30.76º was registered. In both cases the scenes was acquired with sun elevation of 37º. Approximate scale of images was 1:105,000.

3.2 Methodology of the geometrical correction

The methodology of the geometrical correction of the Resurs DK-1 satellite scenes take as one's model of geometrical correction of the very high satellite images such like Ikonos or QuickBird was elaborated by authors of this article. However, in the case of new Russian satellite images the mainly obstacle in the realization of the analogous methodical tasks was lack of the specialist photogrammetric software dedicate for geometrical correction. Distributor of the Russian satellite data made accessible for research project the set of coefficients which was equivalent for Rational Polynomial Coefficients delivered together with Ikonos scenes. The research team was received also files which represented orbital parameters for each scene. These parameters allowed to realization of the own solutions which using proprieties of the internal programistic environment of the PCI Geomatica software. These solutions of the elaboration of the algorithms enabling to realize task of the geometrical correction of the Resurs DK-1 images on the basis of Ortho Engine modules using for Ikonos image data was concerned. Adaptation the recording structure of Resurs DK-1 metadata to the structure of the RPC coefficients format and structure of the orbital data of Ikonos system was the task of these algorithms.

Figure 1. The project of ground control points on the Resurs DK-1 images

For the scenes of Resurs DK-1 covering the Warsaw and Cracow test areas of 28 and 24 ground control points respectively were measured by GPS methods. These points performed interchangeably function of control points as well as check points. The measurement of the image coordinates of ground control points was performed on the modules of Ortho Engine PCI Geomatica software v.10.3. It was assumption that the ground control points should be details unambiguously identified on the image and in the terrain, meanwhile their accuracy of measurement and identification should not be worse

than 0.4m in X, Y plane and 0.3m in height. The example projects of the ground control points showed on the (Figure1). Two geometric correction variants have been used to correct Resurs DK-1 images. The analysis of the influence of number and distribution of the control points in boundary of the scene on the result of geometric correction was realized in each variant. First variant integrates all components of the viewing geometry and sensor as well as the Earth and cartographic projection. In this variant from 5 to 12 well identified and distributed control points was measured. Accuracy of the corrections has been checked on well defined check points. Results are shown in (Tab. 1).

Number of control points for test area Warsaw/Cracow	Number of check points for test area Warsaw/Cracow	RMSE on the check points in meters			
		Warsaw test area		Cracow test area	
		X	Y	X	Y
12	16/12	0.44	0.46	0.44	0.46
10	18/14	0.45	0.47	0.46	0.44
8	20/16	0.46	0.48	0.45	0.46
6	22/18	0.53	0.48	0.57	0.53
5	23/19	0.73	0.82	0.84	0.92

Table 1. Geometric correction results of the Resurs DK-1 images in first variant.

Model of geometric correction of the Resurs DK-1 scenes based on first variant is sufficient for obtained results below half pixel of the source image. The accuracy on 8 independed check points was RMSE X = 0.45m and RMSE Y = 0.46m. Using the orbital parameters of the Resurs DK-1 satellite caused the limitation of measure of control points required for geometric correction. The results obtained in this variant show, what is influence of real orbital satellite parameters on the mathematical model of geometric correction of the Resurs DK-1 images. Obtainment of the results of geometrical correction below one pixel of the source image is possible thanks to use just 5 control points. Enlargement of the number of measured control points to 8 let's get in this variant the optimum result. The second variant of the geometric correction uses a number of ground control points. Unknowns of Rational Polynomial Coefficients (RPC) were calculated on the basis of ground coordinates of control points measured in the field and on the image. The accuracy of RPC parameters depends on the number of control points, accuracy of their identification in the field and on the image, and their distribution on the scene. RPC data have been estimated independently from different number of control points. The results of geometric correction are shown in (Tab. 2).

Number of control points	Number of check points for test area Warsaw/Cracow	Number of polynomial coefficient	RMSE on the check points in meters			
			Warsaw test area		Cracow test area	
			X	Y	X	Y
24	4/0	12	0.32	0.36	0.37	0.36
22	6/2	11	0.34	0.32	0.36	0.38
20	8/4	10	0.40	0.38	0.39	0.38
18	10/6	9	0.45	0.45	0.41	0.44
16	12/8	8	0.52	0.46	0.48	0.45
14	14/10	7	0.58	0.62	0.49	0.55
12	16/12	6	0.76	0.82	0.69	0.71
10	18/14	5	0.82	0.90	0.88	0.97
8	20/16	4	1.04	1.18	1.22	1.34

Table 2. Geometric correction results of the Resurs DK-1 images in second variant.

Delimitation of the optimum degree of the polynomial for estimation of the relationship between image matrix and geodesic coordinate system was the principle in analyzed variants. Obtainment of the result of the geometrical correction on the level of standard deviation of measure and identification of check points is possible during delimitation of 9 polynomial coefficients on the basis of measure 18 control points. Enlargement the number of control points needed for determine of RPC give the result of geometric correction RMSE X = 0.32m and RMSE Y = 0.36m. However in this case the necessity of measurement as much as 4 control points disqualify this variant of geometrical correction. On the basis of results analysis in the individual variants of geometric correction was affirmed that obtainment of the accuracy below one pixel of the source image guarantees the measurement only 10 control points evenly distributed on the scene. Taking into account the economical aspect of geometrical correction of Resurs DK-1 scenes in particular possibility to minimum of limitation of expensive field measurements it should to use the first variant exclusively. However his final choice is determined by the access to original orbital sensor data. Additionally analyzing a' priority and a' posterior errors on the control points it was

affirmed that variant this is most credible in the sense of correctness results. Taking into account exclusively accuracy aspect of geometrical correction of the Resurs DK-1 source images it was affirmed that variant based on independent delimitation of polynomial coefficients is well-founded. It was affirmed that obtainment of the equal results of geometric correction in analyzed variants requires the use as much as 18 control points in the variant basing on RPC delimitation. It should treat this variant as alternative in the case of the bounded access to the full metadata of the Resurs DK-1 image. On the basis of the thorough analysis of the individual variants of geometrical correction was affirmed, that the very high resolution Russian satellite data can be corrected on the level accuracy below half pixel of the source image.

3.3 Requirements of the orthorectification process of the Resurs DK-1 images

The influence of ground height difference on accuracy of orthoimage generated from nadir satellite images is smaller than in case of aerial photographs. Therefore to their orthorectification is possible to use of Digital Elevation Model with less accuracy. The source of this height model can be photogrammetric measurement on the aerial or satellite images with use correlation methods. The accuracy location of the situational details on the orthoimages is depends on accuracy of geometrical correction of the source Resurs DK-1 images. Knowing the orbital parameters and off-nadir viewing angle of satellite the theoretical analysis of orthoimage accuracy in the function of the accuracy of geometric correction of the source images and terrain characteristic was realized. Analyzing of the accuracy of the stage of orthotrctification process of Resurs DK-1 images was affirmed that for purpose of generating of orthoimage which attend of accuracy criterion of topographical map in the scale 1:10,000 it should:

- perform the geometrical correction using sensor orbital data and measure of the minimum 5 ground control points as well as digital elevation model with accuracy better then 12 m;
- perform the geometrical correction of the source images with delimitation of minimum 4 polynomial coefficients and measure of digital elevation model with accuracy better then 6 m.

Taking into account of the recommendation for orthorectification process of the Resurs DK-1 scenes it is easily to notice that influence of terrain denivelation on the orthoimage accuracy is on so many small, that for his elimination in the majority of cases is sufficient measure of height terrain points with accuracy around 4 m. The source of such set points can be correlation methods of the measurement realized on digital aerial images in the scale 1:26,000 or panchromatic very high resolution satellite (VHRS) images for example Ikonos. However the economic aspect of automatic correlation measurement of DEM in the face of requirement of his accuracy caused that in the interest area was founded the Shuttle Radar Topographic Mission (SRTM) program. On the basis of the statistical analysis of SRTM model realized in the Institute of Geodesy and Cartography was affirmed that his accuracy on the area of the Poland is 2.9 m for flat and 5.4 m for hilly terrain. The values of statistical parameters showed that the interferometric measurement contain the systematic error component of height. After elimination this component the absolute accuracy of SRTM model was 1.0 m for flat and 2.7 m for hilly terrains. In the face of above mentioned was showed that the SRTM DTED-1 height data represented each terrain form ensure the accuracy of orthoimages in 1:10,000 scale generate from Resurs DK-1 images.

3.4 Estimation of the orthorectification process of the Resurs DK-1 source images

Estimation of accuracy of the orthorectification process was RMSE characterized accuracy position of situational details on orthophotomaps calculated on the basis of differences between coordinates reading on orthoimages and catalogue coordinates. Analysis of accuracy of orthoimages has been performed using the Image Station Ortho Pro software tools. The orthoimages taking into account the best results of geometrical correction in the individual variants were generated. Estimation of accuracy of orthoimages generated from Resurs DK-1 data has been realized on the basis of 18 independent check points defined for Cracow test area and 23 defined for Warsaw test area. In ortorectification process the corrected data set of the SRTM points with accuracy of 1.1m for Cracow test area and 0.8m for Warsaw test area was used. Results presented in (Tab. 3) refer to the orthoimages generated with 1m pixel size. For all variants of geometrical correction the obtained orthoimage accuracy corresponds to the accuracy of the base maps in scale 1:10,000. Additionally, for variant basing on the use of rigorous mathematical model of satellite sensor of Resurs DK-1 the accuracy was correspond with the accuracy of the base map in scale 1:5,000. It was affirmed, that the accuracy of orthoimages generated with pixel size 0.5 m is only imperceptibly higher.

Characteristic of geometrical correction variant of Resurs DK-1 images	RMSE XY in meters	
	Warsaw test area	Cracow test area
THE QUALITY ASPECT		
Rigorous model with measured of 8 ground control points	0.62	0.61
Polynomial coefficients calculated on the basis of 24 ground control points	0.56	0.61
THE ECONOMICAL ASPECT		
Rigorous model with measured of 5 ground control points	1.12	1.23
Polynomial coefficients calculated on the basis of 12 ground control points	1.66	1.87

Table 3. Results of orthorectification process in quality and economical aspects of geometric correction of the Resurs DK-1 images

The quality aspect of the orthorectification process of the Resurs DK-1 scenes required of measure the large number of ground control on the basis which are calculated RPC coefficients. In the face of doubts connected with the access possibility to the full of Resurs DK-1 metadata the economical aspect reference to the rigorous model of geometric correction on the present day does not have the reason. The economical aspect of the geometric correction of Resurs DK-1 scenes showed the necessity of using the catalogue coefficients of the polynomial. The correlation of these coefficients with the image matrix can correct by measurement a few ground control points.

4. THE COMPARATIVE ANALYSIS OF ELABORATION OF RESURS DK-1 AND IKONOS-2 DATA

The analysis concern to the technical and economic aspects in reference to digital orthoimages generation in 1:10,000 scales was conducted. The orthoimages generated on the basis of the test scenes were the object of the analysis, and in the peculiarity:

- the panchromatic scene of Ikonos system covering the first test area about 121 square kilometers situated in the north-west part of Warsaw which characterized the flat terrain;
- the panchromatic scene of Resurs DK-1 system covering the test area about 144 square kilometers in the center of Warsaw;
- the panchromatic scene of Resurs DK-1 system covering the second test area about 100 square kilometers situated in the north-west part of Cracow which characterized the hilly terrain.

The analysis of the ortorectification process of the Ikonos scene was made in the Institute of Geodesy and Cartography on the basis of research works and technical assessment realized for Ikonos and QuickBird scenes. It was affirmed that in the process of geometrical correction of analyzed scenes in all applied methodical variants is possible to obtain somewhat better results for the panchromatic scene of Ikonos. The higher precision of RPC coefficients delimitation and high internal cohesion of the pixels in the image matrix of Ikonos were the reason of this. The accuracy of geometrical correction of Resurs DK-1 images assuring of the geometric criterion of the topographic map in 1:10,000 scale was obtained in all variants. On the basis of the analysis of the ground control points configuration on the test scenes in function of required results of geometrical correction, it was affirmed, that the costs of field measurements for both were shaped on the same level. It was show that accuracy of orthoimages generated on the basis of the optimum results of the geometrical correction of the source Ikonos scene is somewhat better than accuracy of orthoimages generated on the basis of the optimum results of geometrical correction of the source Resurs DK-1 scene. The orthoimages generated on the basis of test scenes showed on the (Figure2).

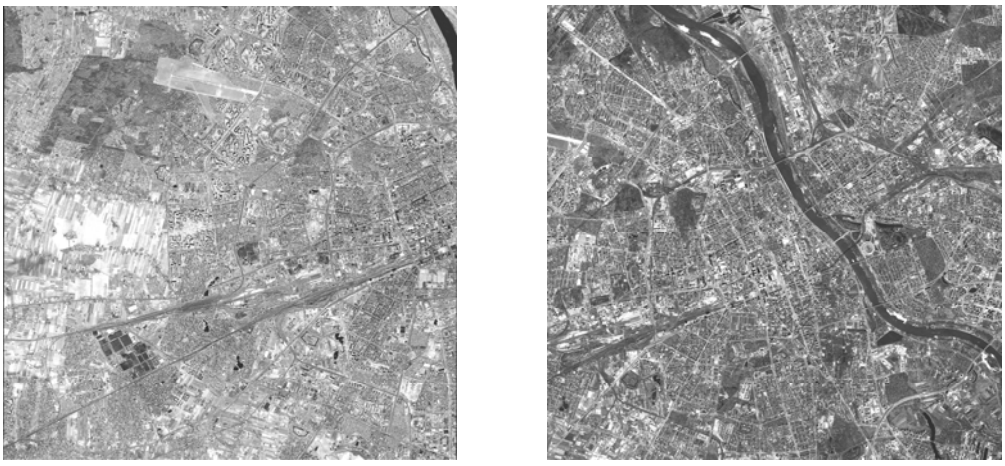

Figure 2. The orthoimages covered the Warsaw test area (Ikonos - on the left, Resurs DK-1 - on the right)

It is result of direct influence of the geometric correction process as well as elimination of influence of the terrain form. The small off-nadir viewing angles of the sensor caused that the geometry deformation of the pixels on comparable orthoimages are mainly function of geometrical correction their source image data. The large values of the elevation collection angles of the compared satellite systems causing that for the correction of the pixel position on the Ikonos and Resurs DK-1 is sufficient digital elevation model with the same standard accuracy
RMSE H = 4m. The source of such height model for both images types can be calibrated set of SRTM points which for all users is free of charge. The reason of applying of the given type of satellite image can be only the scanning cost of the source satellite scene. The price of the programmed scene of Resurs DK-1 covering the surface of one square kilometer is 9.5€ for panchromatic and 13.6€ for multispectral range (pan-sharpened version). The price of archival scenes of Resurs DK-1 is reduce to 8€ and 11 € respectively. The price of one square kilometer of the Ikonos panchromatic scene is about 18€ while the price of the same surface of Ikonos pan-sharpened scene is about 24€. Taking into account all comparative factors it was affirmed, that the higher costs on the commercial market, approximate results and the time consuming of the photogrammetric elaboration of Ikonos and Resurs DK-1 scenes confirmed the necessity of the interest oneself new Russian satellite images. These images together with the development of the Russian satellite systems may in the near future determining new standards in photogrammetry.

5. CONCLUSIONS

The high resolution satellite scenes of Resurs DK-1 are the well source image data for generation of orthoimages in the 1:10,000 scales. The range of this correction is the function of the used methodology, which take into account the rigorous mathematical sensor model influence and RPC coefficients as well as the number and distribution of control points. The transformation of pixels matrix to ground coordinate system is possible to perform with accuracy better than half pixel for each image registered by Resurs DK-1 or Ikonos satellite systems. For the Resurs DK-1 images these accuracy is 0.5 m. The terrain denivelation is necessary to take into account in the rectification process of Resurs DK-1 through involvement to this process of Digital Elevation Model with accuracy better than 4 m. On the basis of the Resurs DK-1 and Ikonos panchromatic scenes the orthoimages can be generated which accuracy corresponds to accuracy of topographic maps in scales from 1:5,000 to 1:10,000 as well as in smaller scales. However, for this range of orthophotomaps scale only geometric standards obligatory in Poland is accomplished but their interpretability refer to 1:10,000 scales only. Taking into account the economic aspect it should affirm that the Russian very high resolution satellite images are competitive in the relation to images of Ikonos satellite system and establish the new source data for generating of the basic photogrammetric products.

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