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ЦИФРОВОЕ ТРАНСФОРМИРОВАНИЕ СПУТНИКОВОГО СНИМКА KOMPSAT 3A И ОЦЕНКА ЕГО ТОЧНОСТИ

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Картографические материалы, особенно крупномасштабные карты и планы, являются важными данными для управления сельским хозяйством и устойчивого развития. Одним из основных методов сбора данных для крупномасштабного сельскохозяйственного картографирования является дистанционное зондирование. Спутниковые снимки, особенно с высоким пространственным разрешением, полученные с различных спутниковых систем, дают подробную, достоверную и точную информацию о сельскохозяйственных угодьях. Спутниковые снимки подвержены искажениям под воздействием различных факторов, многие из которых исправляются в процессе предварительной обработки. Однако изображения, прошедшие только предварительную обработку, не всегда могут соответствовать требованиям составления крупномасштабных карт и планов. Для этого необходимо провести геометрическую коррекцию или трансформирование космических снимков с использованием дополнительных данных, коэффициентов рациональных полиномов (RPC) и координат опорных точек. Данная статья посвящена вопросам трансформирования спутникового снимка высокого пространственного разрешения Kompsat 3A методом полиномов рациональных функций и оценки его точности.

Ключевые слова: *Крупномасштабное картографирование, дистанционное зондирование, космический снимок, трансформирование снимков, модель рациональных функций, опорные точки.*

DIGITAL RECTIFICATION OF THE KOMPSAT 3A SATELLITE IMAGE AND ACCURACY ASSESSMENT

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Cartographic materials, especially large-scale maps and plans, are important data for agricultural management and sustainable development. One of the main data collection methods for large-scale agricultural mapping is remote *sensing. Remote sensing images, especially with high spatial resolution, obtained from various satellite systems, provide detailed, reliable and accurate information about agricultural land. Satellite images are subject to distortion under the influence of various factors, many of which are corrected during pre-processing. However, images that have undergone only preliminary processing cannot always meet the requirements for compiling large-scale maps and plans. To do this, it is necessary to geometric correction or rectification satellite images using additional data, rational polynomial coefficients (RPC) and coordinates of ground control points. This article is devoted to the issues of rectification of satellite image with high spatial resolution Kompsat 3A by the method of polynomials of rational functions and estimation its accuracy.*

Keywords: *Large-scale mapping, remote sensing, satellite image, image rectification, rational functions model, ground control points (GCPs).*

Introduction. Satellite images with very high spatial resolution are very important source of information, especially in large-scale agricultural mapping [1]. Images obtained by different satellite sensors are subject to distortion and require adjustment during processing. In the process of pre-processing, the images are given radiometric, sensory, geometric correction and are brought into a standard cartographic projection. However, images that have undergone only preliminary processing cannot always meet the requirements for compiling large-scale maps and plans. To do this, satellite images are geometrically corrected with the help of additional data (metadata). Such data include rational polynomial coefficients (RPC), coordinates of control points (GCPs), and, if necessary, digital elevation models (DEM). As a result of geometric correction with the additional data determines the relationship between the coordinates (pixel coordinates) of the digital image and the coordinates of points on the ground, and the images are brought to the required cartographic projection. In some literatures this process is called rectification or orthorectification [2; 3].

Digital satellite imagery can be rectified by various methods depending on the existing ancillary data. There are strict, approximation and universal methods of transformation. There are rigorous, approximate and universal methods for rectifying digital satellite images.

A rigorous method, which is the most accurate method of rectification satellite images, provides a mathematical relationship between the coordinates of the image and the terrain based on the physical parameters of the sensor. The use of a rigorous rectification method is limited because the physical parameters of the sensor are not always publicly available [4; 5].

The second most accurate rectification method is the parametric or rational function method. The essence of the this method is to ensure the relationship between the coordinates of the image and the terrain based on the approximation parameters of the sensor, calculated by a rigorous method. For this, the coefficients of rational polynomials (RPC coefficients) are used. The relationship between the coordinates of the image and the terrain can be written in the following form

$$x = \frac{P_1(X,Y,Z)}{P_2(X,Y,Z)},$$
$$y = \frac{P_3(X,Y,Z)}{P_4(X,Y,Z)}. \quad (1)$$

where x, y – normalized coordinates of points in satellite image; X, Y, Z – are normalized spatial coordinates of GCPs, the value of which is normalized between 0 and 1; P_1, P_2, P_3, P_4 – are tertiary polynomials calculated by the following expressions:

$$P_q(X,Y,Z) = \sum_{i=0}^{m1} \sum_{j=0}^{m2} \sum_{k=0}^{m3} a_{ijk} X^i Y^j Z^k \quad (2)$$

where a_{ijk} – polynomial coefficients are provided to users by operators of remote sensing systems (RPC coefficients) [4; 6; 7].

In the course of the study, a Kompsat 3A satellite image with a high spatial resolution of the Republic of Korea was rectified by rational function method. The influence of the number and location of control points within the satellite image on the accuracy of the rectification was also studied.

Main part. Experimental studies on the rectification of a satellite image with high spatial resolution Kompsat 3A (spatial resolution 0.4 m and 1.6 m; deviation angle from nadir - 12°; processing level - 1R) were carried out in the Buka district, Tashkent region (Fig. 1).

Before the transformation of the image, field measurements were carried out at the object of study, as a result of which the positions of the ground control points (GCPs) were determined. As GCPs, solid contours were chosen, such as the angles of rotation of low-rise buildings and structures, their walls, road intersections, road barriers (curbs), the angles of rotation of gas and water pipes, and similar contours. The location of the GCPs was determined from GNSS observations in RTK mode using a Trimble R4 GNSS receiver.

Within the satellite image, 23 evenly distributed GCPs were found, the horizontal and vertical position of which was determined relative to the global ellipsoid WGS-84, in the projection of the UTM 42 zone. Some of the points are designated as GCPs which participated in the rectification, the rest of the points were used as check points (CHPs), which served to assess the accuracy of the rectification of the satellite image (Fig. 2).

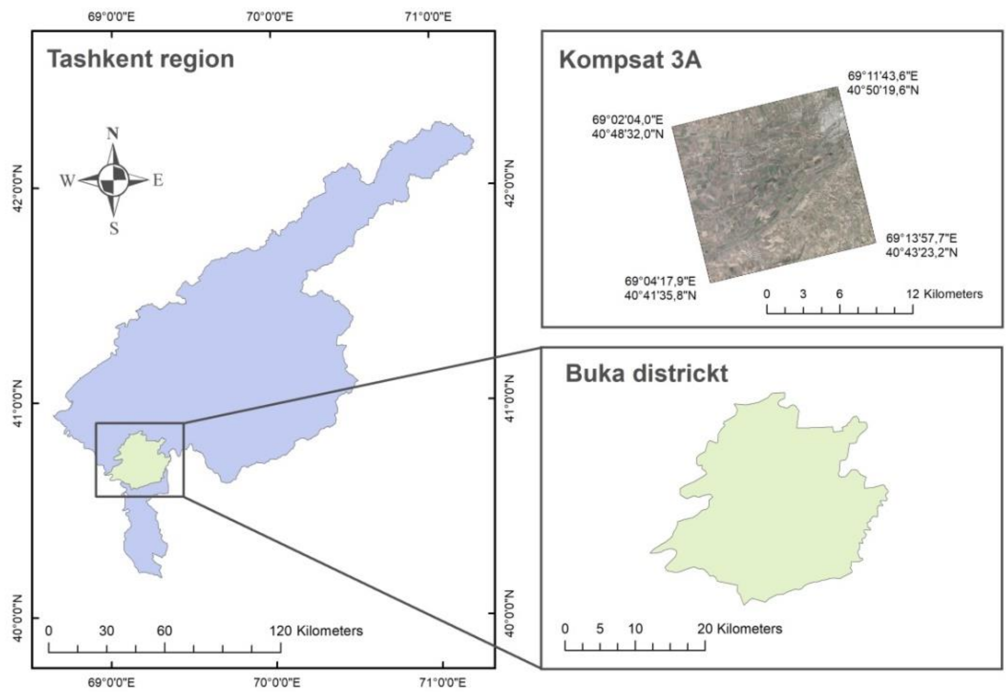

Figure 1. – The area of interest and its location

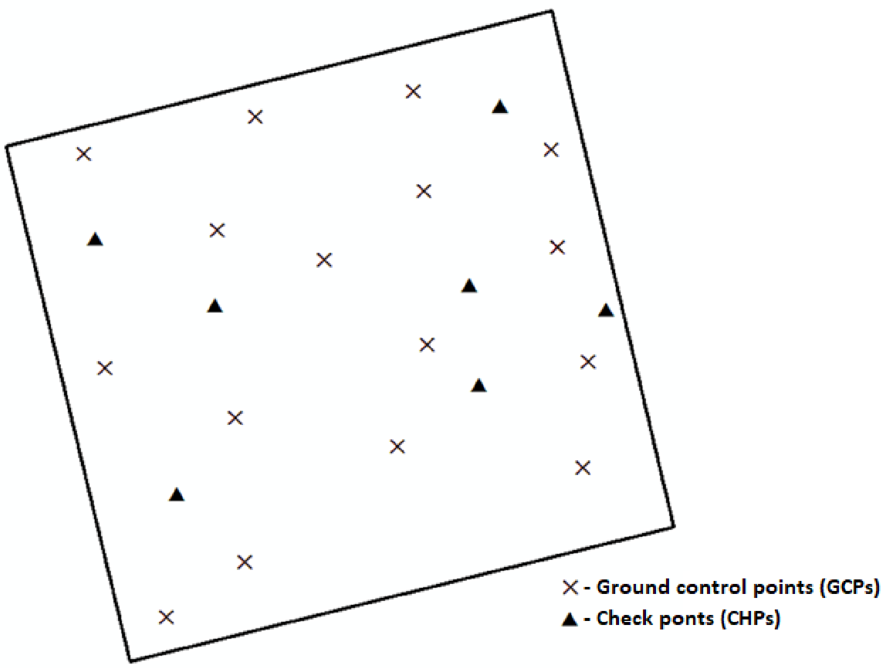

Figure 2. – Distribution of GCPs and CHPs
within the satellite image

The rectification of the Kompsat 3A satellite image was performed in the PCI Geomatica 2016 software by the method of rational function using RPC coefficients, the results of which are shown in Table 1.

Table 1. Satellite image rectification by the method of rational functions

No of GCPs	RMSE, м					
	GCPs			CHPs		
	ΔX	ΔY	ΔL	ΔX	ΔY	ΔL
1	0,03	0,01	0,03	0,48	0,32	0,58
2	0,12	0,54	0,55	0,42	0,60	0,73
3	0,09	0,44	0,45	0,42	0,58	0,72
4	0,09	0,40	0,41	0,42	0,52	0,67
5	0,22	0,69	0,72	0,37	0,34	0,50
6	0,30	0,63	0,70	0,42	0,34	0,54
7	0,34	0,72	0,80	0,38	0,33	0,50
8	0,35	0,67	0,76	0,40	0,33	0,52
9	0,37	0,63	0,73	0,38	0,33	0,50
10	0,36	0,60	0,70	0,37	0,33	0,50
11	0,35	0,58	0,68	0,37	0,32	0,50
12	0,35	0,55	0,65	0,36	0,32	0,48
13	0,36	0,53	0,64	0,36	0,32	0,48
14	0,35	0,52	0,63	0,35	0,33	0,48
15	0,34	0,50	0,60	0,35	0,32	0,47
16	0,33	0,49	0,59	0,36	0,32	0,48

The adjustment results show that the Kompsat 3A satellite image can be accurately oriented using the rational function method using RPC coefficients. The results show that the Kompsat 3A satellite image can be accurately transformed (0.58 m) using only one GCP within the image. With an increase in the number of GCPs to 5, the accuracy at the CHPs increases to 0.50 m. With the number of GCPs 5-16, a sharp increase or worsening of errors is not observed.

Conclusion. The results of the research on the rectification of a satellite image with high spatial resolution Kompsat 3A show that the rectification of the image by the method of rational function using RPC coefficients can provide high-precision output data. The rectification of the image was carried out using 23 evenly distributed GCPs, the horizontal and vertical position of which was determined with high accuracy. The rectification was performed using GCPs located in different parts of the image, which allows us to conclude that the correct or even distribution of GCPs does not significantly affect the accuracy of the rectification.

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