RUSSIAN CONCEPT OF THE SPACE IMAGES DIGITAL PROCESSING

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Working Group IY/ 2

KEY WORDS: DEM, Map, Image, Ortho photo, Remote Sensing, Products.

At present many world countries carry out the mapping of the Earth from space. While doing so all types of mapping products, which have been traditionally developed on the basis of the aero photography, are produced on the basis of space survey materials. The production of several types of such products, for example ortho photo has become more an economically viable and this tendency continues to develop. This tendency is becoming more popular because of the deeper penetration into the world market of the remote sensing data of Russian space images, which by many of its parameters exceed analogues.The report deals with the main characteristics of the basic Russian space images TK-350, KVR-1000 and the technology of their photogrammetric processing which allows to develop DEM, ortho photo and GIS-layers of the digital maps of the scale 1: 10 000 and smaller.

The main problem, which has to be solved at the acquisition of space images in the mapping purposes, consists in the necessity to satisfy to opposite requirements at the Earth survey. First, in space images it is required to have the smallest resolution of the terrain objects. That allows developing maps with the largest possible scale. Secondly, and simultaneously with this requirement the remote sensing data is to cover the max possible area. That provides its minimum cost. The meeting of the first requirement is achieved through the increase of the focal distance of the space images and the meeting of the second one through its reduction. For this reason the optimal solution of the indicated problem can be achieved only on the basis of the distinction of the separate functions of the survey equipment. It is evident that the remote sensing data is worth being divided by the functional property into two types: *topographic* and *deciphering* images. That will naturally define both types of the survey equipment, which will include correspondingly the short focus and long focus cameras.

The concept of the processing of Russian space images is oriented to the mapping of vast territories of the Earth and is based on the joint photogrammetric processing of topographic and deciphering images o proceeding from the principle of their mutual complimentary character. The topographic images have highly developed metrological support. In this connection they serve as the metric basis for the production of DEM and photogrammetric networks. Besides topographic images are used for the precise geodesy referencing of the deciphering images. The deciphering images are designed for the obtaining of ortho photo and GIS-layers of the map.

Up till recently the technology of the processing of space images was built on the use of two met hods:

- on the basis of the use of only navigational data;
- with the use of the points of the field inspection.

The application of the given methods allows developing the end digital products for any Earth terrain including for this or that reason for the inaccessible one.

The digital processing of space images on the basis of only navigational data includes the following technological processes:

- acquisition of “raw” initial image
- development of the geodesy basis;
- production of DEM;
- obtaining of ortho photo;
- development of 3-D images and GIS applications.

The geometrically uncorrected Earth surface images obtained in the result of the aerial survey are the “raw” images as such. But for many users even the “raw” image is a very precious product. With its help one can get to know much information about the terrain which is reflected therein. The deciphering specialist can define the width of the highway, the material of its coverage and the type of the moving vehicles. It is also possible to measure the area of the lakes or the water basin, to define the landscape of the terrain, to identify the types of the trees in the forest and many and many other things.

The most important characteristics of the "raw" image are its *resolution* in the terrain, *the coverage area* and the area of the used light spectrum.

The resolution of the image is the size of the minimum object of the terrain, which still can be identified in the image. This characteristic defines the area of the application of the image and therefore is the most important. For Russian space images the following values of the given parameter are typical:

Type of the image	TK-350	KVR-1000	KFA-1000	MK-4
Resolution, m	10	2	5-7	8-16

Table 1. Resolution Russian space images

The coverage area of the terrain is defined by the physical size of the frame of the image and scale of the image. The larger is the area of coverage by one frame the fewer images will be required to process at the GIS production and the more economical this process will be. The areas of the terrain coverage of TK-350 è KVR-1000 images and the time of the survey are agreed between each other. Therefore their advantages when used for the mapping purposes are evident.

The given images are acquired in the visible zone of the spectrum, which is characterised by the light wavelength within the limits: 400-700 nm. This zone is most informative for the survey of the terrain and that is why it is most frequently used for the space surveys by the high-resolution systems. In this case the images as a rule are made in the black and white panchromatic film, as it is this type of the film which provides the highest resolution provided other conditions are the same.

The acquisition of images in other parts of the spectrum requires the application of the spectrozonal films, which have the selective sensitivity to various light length waves. The ultraviolet area of the spectrum is used little for the remote sensing as it is absorbed significantly by the Earth atmosphere. Another infrared area which is adjacent to the visible band occupies big part of the spectrum: from 700 to 15 000 nm. It is very informative and is widely used in the remote sensing. The spectrozonal images are very effectively used for the deciphering purposes when it is required to detect and identify the terrain objects of certain classes. He parts of the spectrum used at the acquisition of Russian space images are presented in Table 2.

Type of images	**TK-350**	**KVR-1000**	**KFA-1000**	**Ì Ê-4**
Black and white	0.58-0.72	0.58-0.72	0.57-0.62	0.46-0.50 0.52-0.56 0.63-0.69 0.81-0.90
Spectrozonal			0.57-0.68 0.68-0.81	0.57-0.68 0.68-0.81
Colour			0.56-0.81	0.40-0.70 0.58-0.71

Table 2. The acquisition of Russian space images.

The development of the geodesy basis is carried out in two phases. The first of them includes the development of the photogrammetry networks on the basis of the building support routes and inside networks on the basis of TK-350 images. The results of the development of the networks are fixed in the form of the equalled values of the external orientation elements of each image and the geodesy co-ordinates of the terrain points reflected in the zones of the triple overlapping of stereopairs.

In the second phase the obtaining of the plane and height basis is carried out directly to the work places by condensing the geodesy basis up to the required density of the location of the reference points.

The navigational data of TK-350 è KVR-1000 cameras are those parameters of the satellite equipment which are calibrated on the Earth, measured in flight and used at the processing of images in order to define their elements of the external orientation. The navigational data includes: the azimuth of the satellite flight path, the indices of the on-board system of the laser altimeter, star images, indices of the satellite attitude control and positioning systems, the indices of the temperature and pressure sensors inside the section with cameras as well as the precise values of the structural angles between the axes with the same names of the topographic and star cameras. In the process of the installation of cameras in the satellite the curvature of the illumination glass is calibrated and the density of the gas environment inside the section is fixed.

In order to provide the required navigational data in flight the Kometa space system on-board equipment includes:

- navigational equipment;
- two star cameras;
- laser altimeter;
- the system of the synchronisation of the controlling signals.

For the precise definition of the attitude of the satellite in space the solution of the edge task with the use of the images of the star sky is carried out. These images are made by two star cameras synchronously with the images of the topographic camera TK-350. They have the focal distance of 200 mm, the frame format of 12 õ 18 cm and provides the imaging of the stars up to the 6^{th} magnitude of luminosity. The star cameras are structurally rigidly connected with each other and with the topographic camera. All structural angles are calibrated with the accuracy: $RMS_{\alpha,\omega,\chi} = \pm$ 5-10 ″. The star measurements and the calibrated values of the structural angles define the angular elements of the external orientation of the topographic images.

For the calculation of the linear elements of the external orientation the path measurements with the help of the Doppler equipment and laser altimeter are used. The indices of the laser altimeter are used in order to achieve the maximum accuracy of the definition of the photographing altitude: $RMS_i = \pm 5$ m. Such accuracy is achieved at the cost of the small dispersion of their laser beam – of about 20 m in the terrain. The synchronisation of the work of all measurement equipment is carried out with the help of the on-board synchroniser. It allows defining the moment of the start of the work of all the instruments with the accuracy of 10^{-12} s.

The accuracy of the definition of the geodesy co-ordinates and the heights of the terrain points on the basis of only navigational data in TK-350 images amounts to:

$RMS_{x,y} = \pm 20$ m; $RMS_h = \pm 10$ m.

This is enough to compose full value maps of the scale 1 : 50 000. At the use of GPS / Glonass- measurements the accuracy of the photogrammetry definitions increase 2 times. In that case it is possible to produce maps of the scale 1: 25 000 and to produce ortho images up to the scale 1 : 5 000 inclusive. Below the two DEM fragments produced on the basis of TK-350 images with the use of GPS-points and on the map with the scale 1:5 000 are presented.

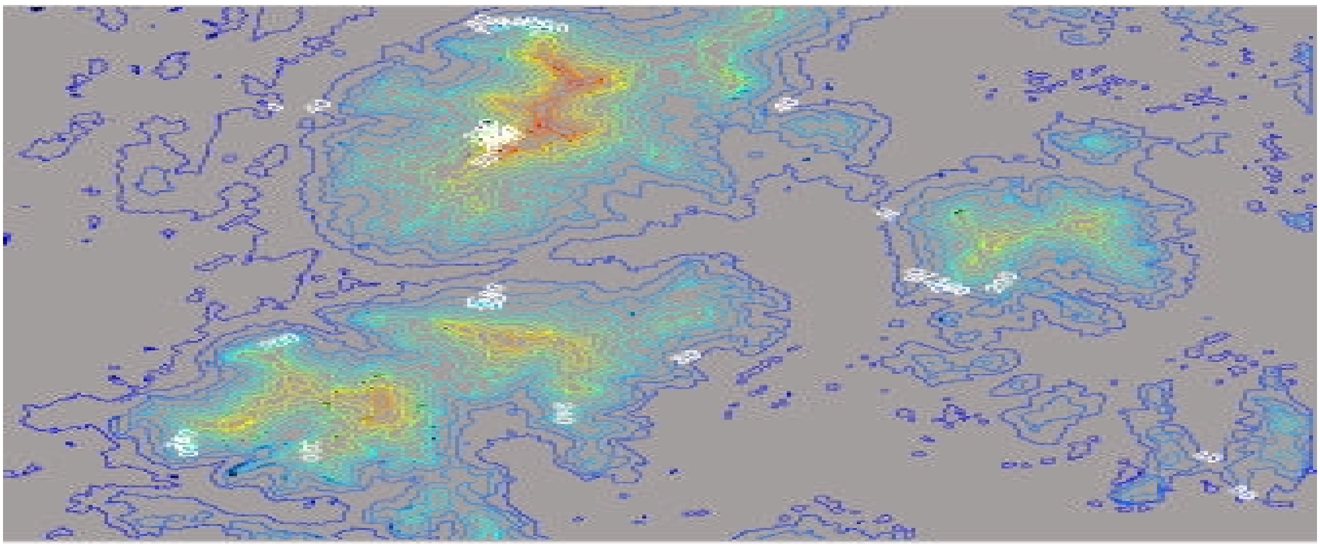

Figure 1. DEM from map 1: 5 000.

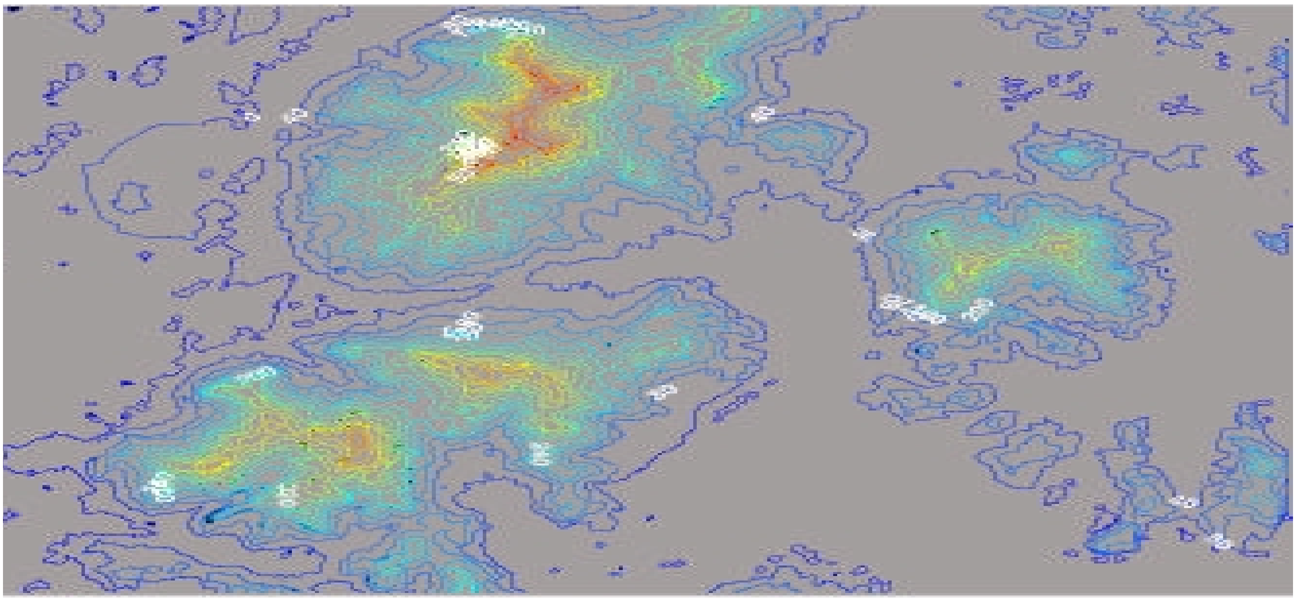

Figure 2. DEM from TK-350

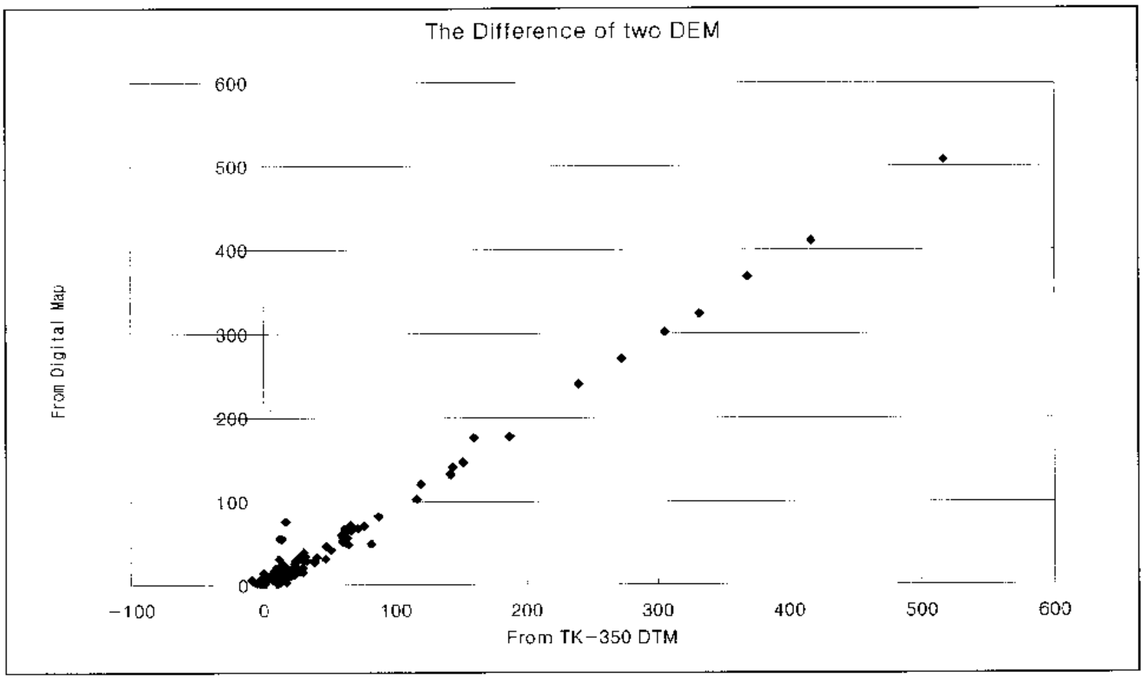

Figure 3. The diagram of the comparison of these DEM shows that the significant differences between them is observed only at the drop of the heights of the terrain points within 100 m takes place, i.e. for the landscape of the valley terrain.

The geometrical model of the scanner image is laid as a basis of the mathematical model of the processed images:

$$X = X_s + \dot{X}_s + (Z - Z_s - \dot{Z}_s)\,\frac{X'}{Z'}; \qquad Y = Y_s + \dot{Y}_s + (Z - Z_s - \dot{Z}_s)\,\frac{Y'}{Z'};$$

$$\dot{X}_s = \dot{V}_x \cdot \Delta t; \quad \dot{Y}_s = \dot{V}_y \cdot \Delta t; \quad \dot{Z}_s = \dot{V}_z \cdot \Delta t; \qquad \begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \Pi\dot{\Pi} \begin{pmatrix} x - x_0 \\ y - y_0 \\ -f \end{pmatrix}; \qquad (1)$$

$$\dot{a} = \dot{V}_a \cdot \Delta t; \quad \dot{w} = \dot{V}_w \cdot \Delta t; \quad \dot{c} = \dot{V}_c \cdot \Delta t;$$

It includes 6 static and 6 dynamic parameters. The static parameters describe the standard model of the framed (aerial) image Other parameters take into account the influence of the dynamics of the real process of the formation of the image at the panoramic scanning of the terrain. The necessity of the dynamic model is determined by the peculiarities of the geometry of the panoramic images. The formation of the KVR-1000 images is carried out as a result of the rotation of two mirrors, which project the terrain objects to the photo film through the immobile slot. While doing so the film moves with the constant velocity within the range of 926 ÷ 1805 mm/s ± 1%. The scanning drive of the camera provides the panoramic unfolding of the terrain through the slot with the angular velocity of $\omega_ï = 0.571 \cdot \rho° \cdot s^{-1}$. At the panoramic angle of $2\alpha = 48°30'$ the time of the formation of the frame is $t = 1.48$ s.

In the KVR-1000 camera the method of the compensation of the shift of the image by the rotation of the objective around the axis which is parallel to the main optical axis and which differs from it the value of the eccentricity **å**. In that case the main point of the objective is shifted at the scanning both along and across the slot by the flat curve. The respective shift values will be defined by the equations:

$$x_0 = e \cdot \sin\omega; \quad y_0 = c + e\,(1 - \cos\omega); \quad \omega = x_ï / f, \qquad (2)$$

where ω - the angle of scanning the current point of the image;

ñ - constant.

In the process of the digital processing the initial images are transformed with account taken of the curvature of the Earth, distortion corrections, internal refraction, shift of the image, shift of the main point, engraving of the reference crosses in the glass and the deformation of the film. The end accuracy of their processing is given in Table 3.

Processed images	**TK-350**	**KVR-1000**	**KFA-1000**	**MK-4**
Accuracy of processing of images on the basis of navigational data				
RMSx,y	20-25 ì	20-25 ì	20-25 ì	25-30 ì
RMSh	10 ì	-	-	40-45 ì
Accuracy of the processing of images on the basis of additional GPS-points				
RMSx,y	7-10 m	2-3 m	5 m	8 m
RMSh	4-5 m	-	-	30-34 m

Table 3. The accuracy of processing of russian space images.

The described technology of processing Russian space images makes the Russian concept of mapping universal and very competitive.