THE USE OF RUSSIAN TK-350 IMAGES AND GPS POINTS IN GENERATION OF DEM.

Mikhail M. Fomtchenko, General Director, SOVINFORMSPUTNIK, Russia,
Vladimir F. Chekalin, Senior Researcher, Sc.D., SOVINFORMSPUTNIK, Russia

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ABSTRACT:

At the meantime new types of remote sensing data appear on the international market. The data are TK-350 and KVR-1000 images which are used for large areas mapping. The area covered by one TK-350 image of 1:660 000 scale is 200 x 300 km. Same area is evenly covered by seven KVR-1000 images of 1:220 000 average scale. Both types of images are taken simultaneously and this imagery allows to perform full-value terrain mapping with 1:50 000 scale and smaller.

To produce such maps joint photogrammetric processing of above mentioned images is to be carried out. Topographic images TK-350 serve as metric basis for production of terrain model. This model is measured with the purpose of manufacturing of DTM and KVR-1000 imagery geo-referencing.

One of the main advantages of Russian images is that no additional information about ground surface is needed to produce maps. Accuracy of DTM generated on a basis of TK-350 images is +/-15-20 m (RMS) in plane and +/-7-10 m (RMS) in height.

Geo-referenced interpretation images KVR-1000 are used for production of orthoimages of up to 1:10 000 scale. Two meter resolution of these images allows to make enlarged copies of the said scale without loss of details.

Much more capabilities for the users of KVR-1000 and TK-350 images become possible if GPS points are used. Even if just one GPS point per 150 square kilometers is available accuracy of DTM can be improved up to 5 m in height.

In connection with Russia's active coming out onto the international market of remote sensing data obtained by TK-350 and KVR-1000 cameras, the technology of joint photogrammetric processing of these images is of indubitable interest for the users. According to the ideology of such processing accepted in Russia, TK-350 images serve as metric basis in producing of geometric terrain model with its subsequent measuring. At the same time KVR-1000 images are the carriers of high resolution imagery for production of measuring cartographic documents.

Unique case is obtaining of information on terrain relief by means of stereoscopic survey by KVR-1000 images. It allows to produce DTM with RMS in height of 3-4 m. In so doing direct photogrammetric determinations are made using KVR-1000 imagery stereopairs, and measurements of TK-350 images serve to equalize the results of geo-coding of the former and to control rough errors.

Joint processing of TK-350 and KVR-1000 images provides an obtaining of full-value cartographic products with the minimum number of required geodetic control points. These control points are used to develop geometric terrain model using TK-350 images. From this terrain model measuring information required for geo-referencing of KVR-1000 images is taken by means of identification of the same ground points. Geodetic coordinates of these points are defined with the help of already produced geometric terrain model.

According to the approach above described, TK-350 images must have highly developed metrologic supply. In practice, using analytic stereoscopic devices, it allows to measure TK-350 images with 8-10 mkm accuracy. KVR-1000 images must have sufficient accuracy of mutual location and ground resolution of objects. At the same time all characteristics of both types of images are coordinated between each other in the process of survey.

According to the announcement of DMA (United States Defense Mapping Agency) which has conducted a study of photogrammetric processing of these data, the accuracy of triangulation performance for TK-350 images is approximately 9 m in plane and 16 m in height. The obtained correlation of quantitative values of errors of ground points location in plane and in height does not seem to be typical for TK-350 imagery, and as follows from the analyses of DMA report, is caused by non-consideration of a number of metrological parameters of the imagery. Detailed description of how the main distorting factors affect the geometry of these images is presented in the report of Dr. Viktor N. Lavrov ("Sovinformsputnik", Russia).

Association "Sovinformsputnik", possessing an exclusive right to sell TK-350 imagery, is in position to supply special methods of consideration of corresponding metrologic parameters of this imagery and to provide users with necessary assistance in adjusting of technological process. Expected accuracy of photogrammetric processing of TK-350 and KVR-1000 images is defined by the following equation:

$$\mu^2 = 6/n\,[m^2_{x,y} + m^2_{mod.} + 1/t^2\,(M^2_{x,y} + (r^2/f^2\cos^2\varepsilon)M^2_H)], \quad (1)$$

where:

μ - resulting RMS error of ground points coordinates determination (in the image scale);

$m_{x,y}$ - RMS error of the image points measurement;

$m_{mod.}$ - RMS error of the image mathematic model of geometry;

$M_{x,y,H}$ - RMS error of the location of geodetic basis control points;

t - image scale;

ε - inclination angle of the image;

r - maximum distance of the points being determined from the point of nadir of the image;

n - number of control points of geodetic basis.

The value of RMS error $m_{x,y}$ depends on a range of factors, affecting during the execution of technological process. The main ones are: resolving power of the image, psycho-physiological abilities of the operator and instrumental accuracy of measuring device used.

RMS error $m_{mod.}$ is defined by the degree to which mathematical description of the law of imagery is adequate to real physical processes being in force at the moment of taking picture.

The values of RMS errors $M_{x,y,H}$ are determined by the method of the image planimetric-height basis production.
In consideration of regularity of action of errors mentioned, all the above said can be graphically presented in the following way:

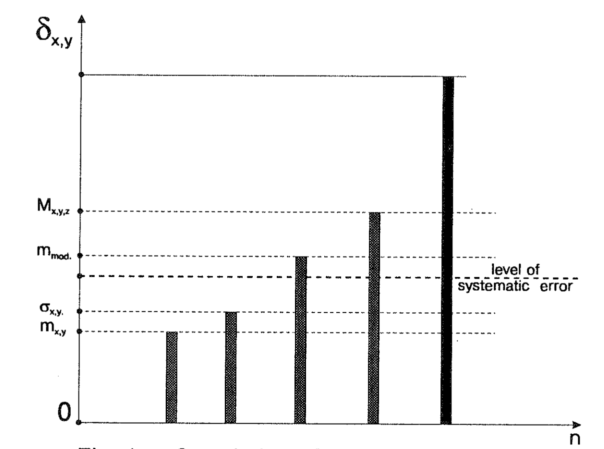

Fig. 1 Correlation of accidental and systematic errors of general error μ of the image.

Measuring capabilities of the image define theoretical accuracy limit $\sigma_{x,y}$ of its photogrammetric processing. For TK-350 images it is in 7 - 8 mkm range, for KVR-1000 images it is equal to 5 -6 mkm approximately.
The error induced by the operator in identifying of ground objects on the image is determined, mainly, by the resolving power of the image:

$$m_{id} = 1000 \text{ mkm} / 4.1 R_{image} \qquad (2)$$

where
m_{id} - RMS error of identification of ground objects on the image;

R_{image} - resolving power of the image.

For TK-350 imagery the accuracy of ground objects identification in consideration of resolving power of its representation on the image is on the level of 8 mkm, for KVR-1000 imagery this parameter approximately equals to 4-6 mkm.

The degree of strictness of the image mathematic model is determined by the level of remaining errors occurred due to consideration of the image geometry distortion. For TK-350 imagery such distortion is caused by deviations from the law of imagery in ideal central projection. Practically, for taking these deviations into consideration, the grid of control crosses is printed in along the field of the image. Coordinates of these crosses are calibrated in outer bunch of projecting beams. Step of the grid is 1 cm. Using this grid geometric distortion of the image can be corrected with the accuracy 4-5 mkm. For KVR-1000 data the most strict factor is a dynamic model of the image geometry forming. This model corrects the satellite's movements during the time of film exposure, distortion and de-centering of panoramic satellite camera's lens system scanning part, as well as varying displacement of the main point in panoramying the image. Practical investigations made by the author show that using dynamic model, determination errors of KVR-1000 panoramic imagery law are in the limits of 14-17 mkm.

In producing of planimetric-height basis of TK-350 image by means of photo triangulation development the main component is the value of the errors in geodetic reference points location. Figure 2 demonstrates the plot of photo-triangulation accuracy for TK-350 images drawn out on the following conditions:

$m_{id} = \pm 8$ mkm;	$m_{mod} = 4\text{-}5$ mkm;	n = 20;
$m_{x,y} = 7\text{-}8$ mkm;	$\varepsilon = 1^0$;	f = 350 mm;
	$r^{max} = \pm 22.5$ cm.	

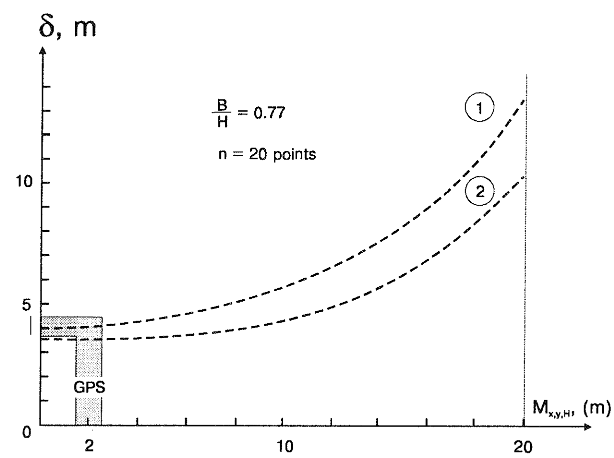

Fig. 2 Accuracy of photo-triangulation development for TK-350 images (curve 1 - in plane, curve 2 - in height).

Curve No.1 characterizes the accuracy of determination of geodetic coordinates of ground points in plane, curve No. 2 - in height. From the plot one can see that on the basis of TK-350 images terrain mapping can be performed with the accuracy 13.5 m in plane and 10.4 m in height. This accuracy is sufficient to produce full-value topographic maps of 1:50.000 scale.

Using measurements provided by two operators, the accuracy of DEM is 7-10 m in height.

Mode of KVR-1000 imagery forming makes conditional necessarily of use of dynamic model of its geometry, which takes into consideration movements of the spacecraft and camera's scanning lens. But, increasing of number of calibration parameters to be determined leads to deterioration of determinability of equation system in resolving the problem of its geodetic referencing. As practice shows, depending on amount and location of control points the number cond A is increased by 10-20 times in comparison with frame image.

To achieve numerical stability of corresponding iteration process and to increase accuracy of definition of coordinates of KVR-1000 imagery ground points geodetic referencing of this imagery is made using method of singular decomposition on the basis of GPS points. In this case accuracy of generated ortho-photo is increased up to 4-5 m. Provided aerial photographs are available over the same area, it becomes possible to produce composed orthophotoplan of 1:10 000 scale.