INCREASING OF ACCURACY OF EXTERIOR ORIENTATION OF TK-350 SATELLITE IMAGES

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ABSTRACT:

The paper considers the conditions for increasing of accuracy of exterior orientation of TK-350 images (medium resolution) - the use of highly accurate control points and joint processing of a medium resolution image and a high resolution image. There is proposed a method for increasing of accuracy of exterior orientation due to creation of stereo model from high resolution image and medium resolution image and transferring of ground control points from high resolution image to medium resolution image. It is shown that the accuracy of exterior orientation of TK-350 image can be of the same order as accuracy of recognition of control points on high resolution image.

1. INTRODUCTION

At present time in using of remote sensing data there is a stable tendency to use images of higher and higher resolution. However, some users also employ medium resolution images (ground resolution about 10m). In this connection there arises a task of accurate rectification of such images. Besides this, it is very topically to produce highly accurate Digital Elevation Model (DEM) both for the process of orthorectification and for direct use in GIS. TK-350 images obtained by the Russian satellite system Kometa can serve as basis both for production of medium resolution orthoimages and for production of highly accurate DEM.

2. RUSSIAN SATELLITE SYSTEM KOMETA AND ITS ACCURACY CHARACTERISTICS

Russian satellite system Kometa is developed and used for mapping of large territories of the Earth. One mission provides stereo coverage of the terrain within 50,000,000 sq.km. by TK-350 images and 20,000,000 by KVR-1000 images. Topographic images TK-350 provide continuous stereo coverage of the terrain within 200 km swath with 10m resolution. Detailed KVR-1000 images provide mono coverage with 2m resolution. Just the presence of synchronous coverage by medium resolution TK-350 stereopair and high resolution KVR-1000 images used for more reliable interpretation of objects allows to significantly increase the accuracy of DEM. This increasing of accuracy of DEM produced on the basis of Kometa data using the method of subpixel correlation (Zheltov, 1997) is achieved by increasing of accuracy of exterior orientation of the stereomodel as well as of a single TK-350 image.

3. METHODOLOGY OF EXTERIOR ORIENTATION

For exterior orientation of a single image or stereomodel there are used control points obtained from photogrammetric networks with characteristic accuracy 15-20m or control points from maps accuracy of which depends on map scale. Therefore, the accuracy of exterior orientation obtained on the basis of such points is determined by the accuracy of control points and resolution of TK-350 images (10-12m). At present time there is such source of control information as GPS points. Their accuracy reaches 0.1 – 1 m. However it is impossible to use GPS points directly without loss of accuracy because the accuracy of recognition of a GPS point on a 10-12m resolution TK-350 image can not be much higher than this value of 10-12m.

In order to increase the accuracy of exterior orientation the following technique is proposed. On the first stage GPS points are recognized on a high resolution image. Then a point is transferred to a medium resolution TK-350 image. Then exterior orientation of TK-350 image or stereopair is performed. The high resolution images can be KVR-1000 or IKONOS images.

The transfer of control points from high resolution image to medium resolution images can be done using polynomials of various orders. The coefficients of polynomial are determined by adjustment of coordinates of the same points on high resolution image and medium resolution image. However, this method doesn't take into account terrain height. Therefore, the accuracy of this method is not sufficient for solving of the task. An alternative is transfer of a point using frame image model taking heights into account.

Let's consider the scheme of location of high resolution images and medium resolution images (Fig.1). Where P1 is the left image of stereopair, P2 is the right image of stereopair – the high resolution image. S1, S2 are corresponding centers of projection of the images. Recognition of control points is made on high resolution image P2. Say, this is point m2 (see Fig.1) on high resolution image corresponding to point M on the ground. The point M on the ground is shown on the left image of stereopair as point ml and it is shown on the right image of stereopair as point mr.

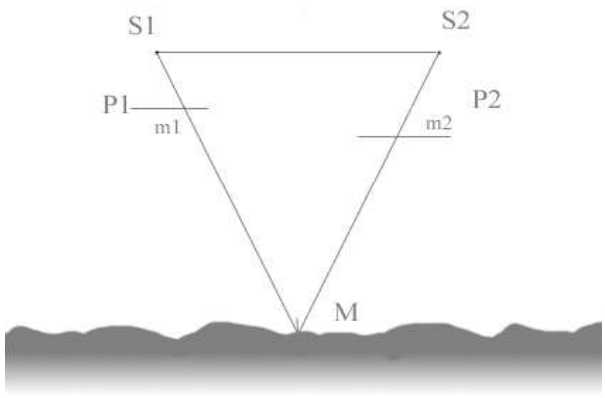

Figure 1. Scheme of location of high resolution images and medium resolution images

The task is to restore the exact location of point M on the left image of stereopair (m1). For this purpose a terrain model is built from the stereopair but exterior orientation of the model is not performed. That is, there is built a free model arbitrarily oriented in geodetic space. In this case a specific feature of this stereomodel is that it is built from images with different spatial resolutions.

For the images of stereopair from coordinates of the same points under the coplanar condition

$$R_0 \times (R_1 \times R_2) = 0 \quad (1)$$

there are determined the elements of relative orientation (for the left image: Alpha1, Omega1=0, Kappa1, for the right image: Alpha2, Omega2, Kappa2).

4. TRANSFER OF CONTROL POINTS FROM HIGH RESOLUTION IMAGE TO MEDIUM RESOLUTION IMAGE

On the first step recognition of control points is made on high resolution image. For each control point I we obtain a set of coordinates x_i, y_i.

On the second step a local DEM is built for neighborhood of a control point. Since exterior orientation of the stereomodel was not performed then the DEM will be obtained in a free coordinate system..

On the third step for each control point we determine its coordinates in a free coordinate system of the stereomodel (Lobanov, 1984). For connection of coordinates on high resolution image and coordinates of free stereomodel we can write down the following:

$$X-X_{s2}=(Z-Z_{s2})*X'/Z' \quad (2)$$
$$Y-Y_{s2}=(Z-Z_{s2})*Y'/Z' \quad ,$$

where

$$X'=a_1(x-x_0)+a_2(y-y_0)-a_3 f_2$$
$$Y'=b_1(x-x_0)+b_2(y-y_0)-b_3 f_2$$
$$Z'=c_1(x-x_0)+c_2(y-y_0)-c_3 f_2$$

Since the Z coordinate of a control point is not known accurately then the coordinates are determined by an iterative method. At the first iteration Z coordinate is set to some average height value. At the next iteration the height value is corrected from the obtained X, Y coordinates and local DEM. And so on until the error in coordinates becomes lower then the required threshold.

On the last step we perform recalculation of coordinates of a control point from the coordinates of free model to the coordinates on medium resolution image using the following formulas:

$$x-x_0= - f_1*X''/Z'' \quad (3)$$
$$y-y_0= - f_1*Y''/Z'' \quad ,$$

where

$$X'=a_1(X-X_{s1})+b_1(Y-Y_{s1})+c_1*(Z-Z_{s1})$$
$$Y'=a_2(X-X_{s1})+b_2(Y-Y_{s1})+c_2*(Z-Z_{s1})$$
$$Z'=a_3(X-X_{s1})+b_3(Y-Y_{s1})+c_3*(Z-Z_{s1})$$

The described technique allows to take into account the terrain height (which is not allowed by other methods using polynomials) for each control point and hence highly increase the accuracy of transfer of points from a high resolution image to a medium resolution image.

5. CONCLUSION

Solving of the problem of increasing of accuracy of exterior orientation of TK-350 images is provided by substitution of direct exterior orientation of images using control points with a two-stage process: (I) relative orientation of images of stereomodel and (ii) transfer of control points to a medium resolution image. It is proven practically that the accuracy of relative orientation is significantly higher than the accuracy of exterior orientation. The remainder vertical parallax can be 0.01 pixel that is in case of pixel size corresponding to 10m on the ground the accuracy of orientation is 0.1m For exterior orientation of a high resolution image the accuracy can be 1-1.5 pixel. That corresponds to 2 –3 m for 2m resolution KVR-1000 images and to 1 – 1.5 m for 1m resolution IKONOS images accordingly. Thus, the resulting accuracy of exterior orientation of TK-350 images is determined by the accuracy limit of orientation of a high resolution image and can equal from 1 to 3 meters on the ground.

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