

INVESTIGATION OF ERROR DISTRIBUTION OF AERIAL TRIANGULATION APPLYING SURFACE DEFORMATION THEORY

Birute RUZGIENE, Vincas VAINAUSKAS
Vilnius Gediminas Technical University, Lithuania
Department of Geodesy and Cadastre
Birute.Ruzgiene@ap.vtu.lt

KEY WORDS: Aerial Triangulation, Accuracy, Deformation, GPS, Simulation, Modeling, Network, Software.

ABSTRACT

The world of photogrammetry has changed rapidly. A new aerial triangulation approach, where the main aspect is the usage of perspective center coordinates determined by kinematics GPS, was used for creating photogrammetric control on the area of city Vilnius. This paper presents results of aerial triangulation network simulation analyzing theoretical, absolute (factual) and relative (interior) accuracy of the simulated network. There is shown possibility of adaptation of the surface deformation theory for investigation of RMSE distribution and geometry representation in aerial triangulation adjustments. By use of the approach of surface deformation theory with graphical representations it is the easiest way to detect the systematic errors and define pseudosystematic and partly random deformation of photogrammetric network model.

1. INTRODUCTION

The physical model of object that is deformed by the systematic and random measurement errors may be reconstructed by aerial triangulation approach. Photogrammetric networks differ from usual geodetic control networks, where errors mostly are of random and systematic nature and they can be eliminated by the additional geodetic measurements. In the photogrammetric networks there are appearing as one single as other double summation measurement errors including the systematic linear and quadratic accumulation errors. Therefore we have the reason for determination of the true character of aerial block network deformations and then for approval of correct approach in eliminating them to suggest the theory of surface deformation.

On the basis of aerial photography at a scale of 1:6000 the experimental aerial triangulation network with kinematic GPS support and 25 geodetic control points was created. Empirical simulation of big size and irregular configuration aerial triangulation photogrammetric block (see Figure 1) was carried out.

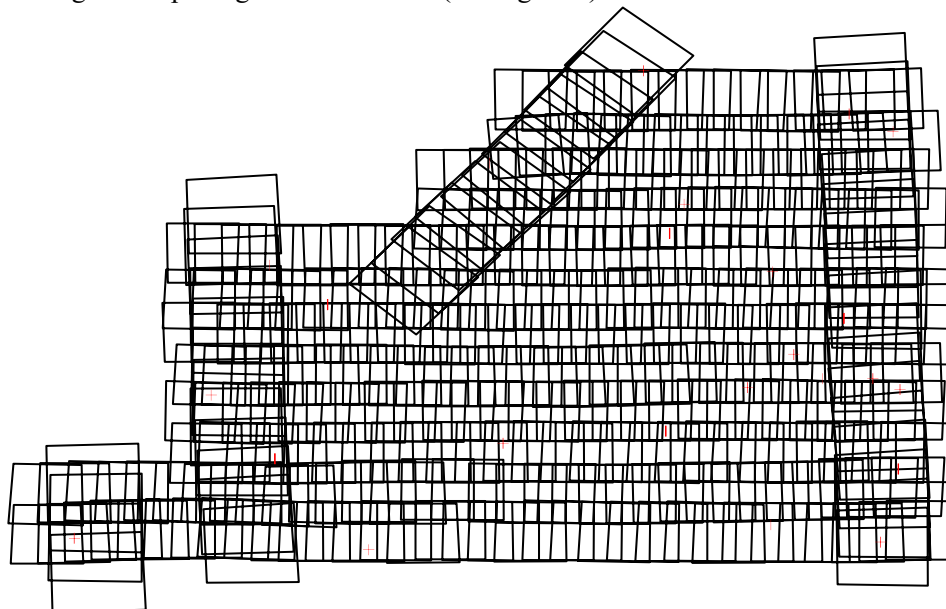


Figure 1. Scheme of aerial photography strips and control points

2. EXPRESSION OF DEFORMATION

Experimental aerial triangulation network had been investigated for determination of surface deformation with regard to various options of support. There was applied the strong method of adjustment under the use of collinearity condition for ensuring better and reliable results and data of accuracy.

For simulation of block network adjustment were chosen 7 options: 1. Kinematic GPS-photogrammetric network (standard); 2. Traditional photogrammetric network including transverse strips; 3. Traditional aerial triangulation network; 4. Kinematic GPS-photogrammetric network not involving inner orientation parameters; 5. Kinematic GPS-photogrammetric network with minimum control points; 6. Traditional aerial triangulation network with minimum control points; 7. Kinematic GPS-photogrammetric network without any control points.

Accuracy analysis of simulated aerial triangulation block network is carried out concerning to theoretical, absolute (factual) and relative (inner) accuracy. For analysis of factual network accuracy was selected the most characteristic options of block adjustment and mean square errors calculated with respect to block network adjustment of maximum accuracy.

Particularly two options of simulated block network adjustment were chosen and deposited: hybrid (standard) and traditional network with minimum of control points. In hybrid aerial triangulation controlled by the kinematic GPS support the planimetric RMSE was obtained that does not exceed 2-5 cm, when theoretical accuracy in planimetry of aerial triangulation (traditional) with minimum geodetic support had been received 16-17 cm (cf. Table 1). In this case estimating practical (factual) accuracy for aerial triangulation network relating to control positions (according to coordinate discrepancies) RMSE in planimetry have been obtained ≈ 2 times lower than one's theoretical accuracy and in altimetry ≈ 20 times. In option of minimum geodetic control distribution comparing with standard option the practical accuracy are much more largely, namely ordinates approximately - 10 times, heights - 100 times.

Options	Theoretical accuracy, m				σ , μm	Practical accuracy, m		
	Number of control points	\bar{m}_x	\bar{m}_y	\bar{m}_z		$\bar{\mu}_x$	$\bar{\mu}_y$	$\bar{\mu}_z$
1	25	0.04	0.03	0.07	5.8			
2	25	0.04	0.04	0.10	6.0			
3	25	0.07	0.04	0.11	5.5	0.05	0.04	0.14
4	25	0.05	0.04	0.09	6.7			
5	4	0.05	0.05	0.10	5.8	0.05	0.03	0.06
6	4	0.16	0.17	0.46	5.4	0.25	0.47	8.07
7	-	0.10	0.11	0.38	5.8	0.07	0.07	0.14

Table 1. Estimation of theoretical accuracy of block network and practical accuracy relating to control position

It has made clear that after block network adjustment the theoretical accuracy evaluated according to variance matrix data does not always correspond to the reality.

Under the use the software STATGRAF 5.0 there was provided the statistical error analysis, when frequency intervals were approximately chosen as equal to 1/2 m. The obtained coordinate discrepancies are not always rigorously dispersed according to the normal law distribution, because exist the residual systematic coordinate displacement, namely for option 3 the coordinate discrepancies correspond to the normal law distribution, when for option 5 and 7 the coordinate discrepancies are influenced by pseudosystematic errors and essentially strong influence of pseudosystematic errors is seen in option 6. In such a way the surface deformation theory was adopted for investigation the character of aerial triangulation by mean square error distribution.

3. DISTRIBUTION OF AERIAL TRIANGULATION ERRORS

Aerial triangulation network of maximum accuracy and traditional aerial triangulation network with minimum control points had been performed and investigated for determination of surface deformation. According to mean square errors of 1355 photogrammetric points gained after the two options of block network adjustment by use software WINSURF were compiled color izograms that reflect the surface deformation.

Analysis of these surface deformations was carried out by comparison method. In the case of standard option of network adjustment there were calculated mean square errors according variance matrix. The theoretical errors practically distribute evenly, homogenous over the entire area of network, with exception of weak area of network - namely margins and corners (Figure 2). It should be affirm that accuracy for all points is homogeneous and in the entire area of network does not exceed 2-4 cm in planimetry and 5-7 cm in altimetry.

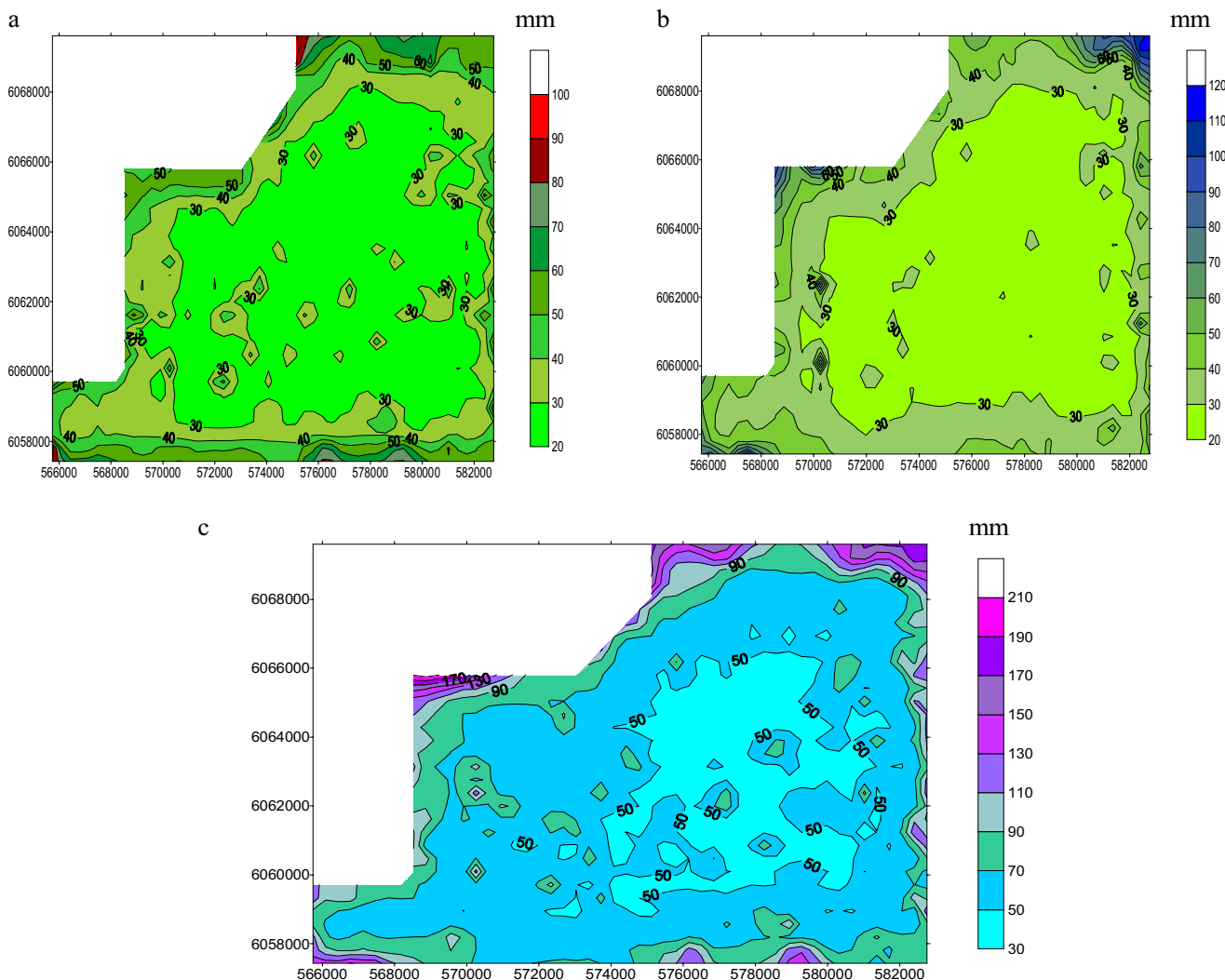


Figure 2. Izograms of mean square errors of photogrammetric point coordinates of aerial triangulation network’ s standard variant: a - abscises, b - ordinates, c - heights

Consequently, izograms have been compiled on the basis of comparison of two options (standard and traditional) by computing for all photogrammetric point coordinates the discrepancies that correspond to real accuracy (see Figure 3).

After evaluation of factual accuracy of aerial triangulation network with minimum geodetic support, it is defined those surface deformation hyperboloids or paraboloids which have expressed by coordinate discrepancies comparing with standard option. Surface deformation of planimetric coordinates is represented by hyperboloidic surfaces when altimetric discrepancies are the ideal surface deformation paraboloid, extend in flight direction. It approves similarity of the residual deformation of photogrammetric stereopair model, which by outer orientation could be expressed by polynoms of two variable of high degree. In this case it characterize the common deformation of aerial triangulation network. Furthermore, information in this matter does not reflect accuracy, gained by evaluating the theoretical accuracy of the aerial triangulation network according to variance matrix.

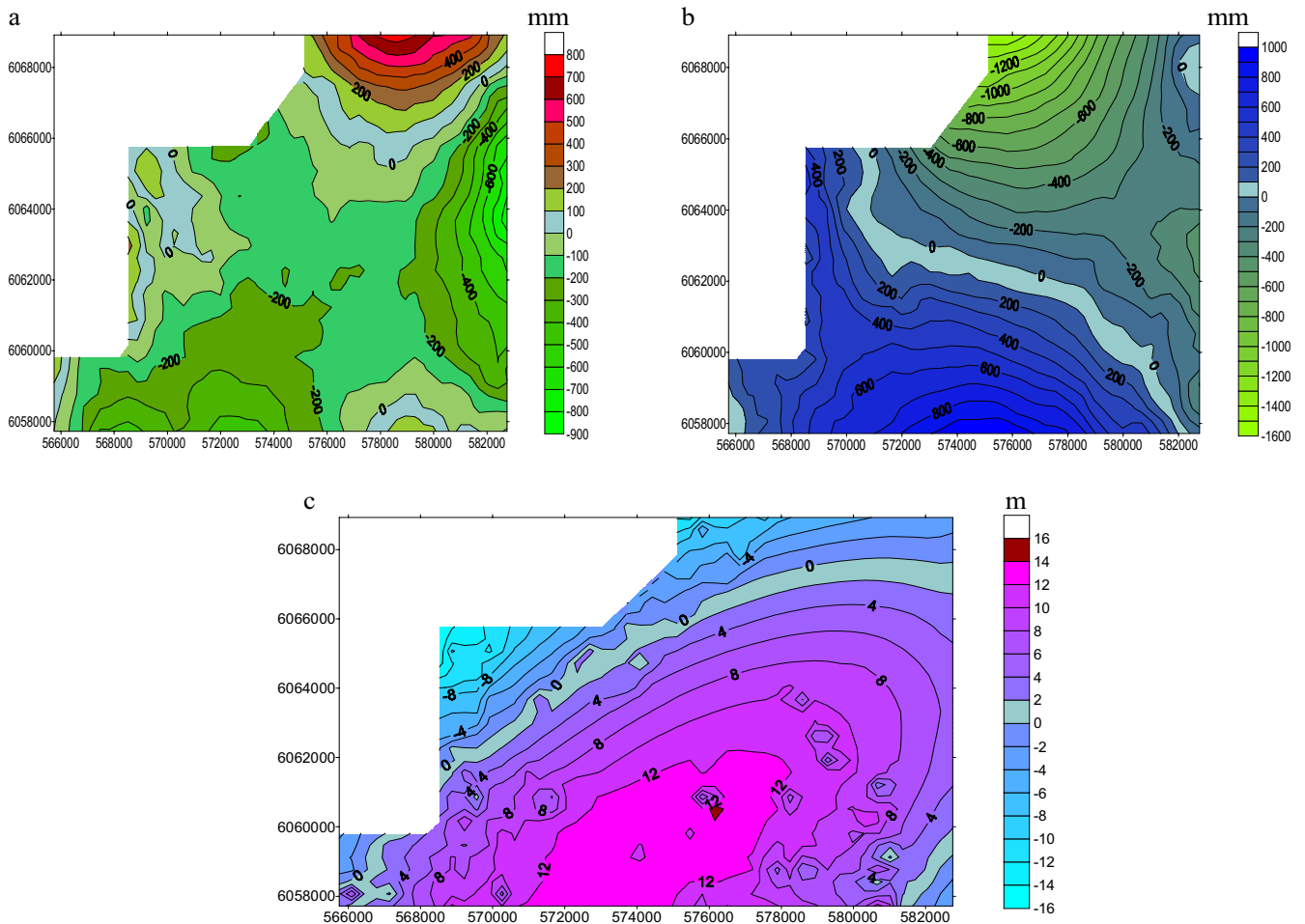


Figure 3. Izograms of discrepancies of photogrammetric point coordinates of minimum support aerial triangulation network with respect to standard network adjustment: a - abscises, b - ordinates, c - heights

4. CONCLUSIONS

It is shown that number of control points in hybrid GPS-photogrammetric network could be reduced to minimum (3-5 points) or controlled only by kinematic GPS, when RMS of planimetric point coordinates do not exceed 5 cm and 10 cm for heights. Furthermore, the theoretical accuracy obtained according to variance matrixes do not always corresponds to the reality, especially, when the network is not controlled by additional independent geodetic measurements. By use approach of the surface deformation theory with graphical representation it is the easiest way to detect the systematic errors and define pseudo systematic and partly random deformation of photogrammetric model geometry and by statistical analyses to show the influence of systematic bias and, consequently, to reach the accuracy of 3-5 cm.

5. REFERENCES

- Ruzgiene B., Zalnierukas A., 1998. Aerotrianguliacija naudojant kinematinio GPS rezultatus. *Geodezija ir kartografija*, XXIV t., Nr. 1, Vilnius, pp. 16-25.
- Vainauskas V., 1979. Sistema modelej optimizaciji i oenki geodeziceskich i fotogrammetriceskich opornich setej. *Geodezija i kartografija*, N8, Moskva, pp. 23-30.
- Vainauskas V., Pilipaitis A., 1990. Numerical photogrammetry of architectural and archaeological heritage. *International Committee of Architectural Photogrammetry, 13 International Symposium, Krakow*, pp. 275-280.
- Sokolov O., 1998. O raspredelenie slucainoj osibki izmerenij. *Geodezija i kartografija*, No. 1, Moskva, pp.22-27.
- Frieß P., 1988. Empirical accuracy of positions computed from airborne GPS data. *International Archives of Photogrammetry and Remote Sensing*, Vol. 27, Part B3, Kyoto, pp.215-234.