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The Effect of Various Principles of External Orientation on the Overall Triangulation Accuracy

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One of the most important parts of photogrammetry is making orthophoto mosaic and its accuracy. Aerial triangulation is one of the integral parts of making orthophoto mosaic and its accuracy. All over the world various softwares are used to make orthophoto mosaics. N. Liba et al. (2008) and they offer different opportunities related to the photos captured by matrix or also with strip sensors. If a photo is captured by a matrix sensor, it has two or three overlapping areas and, additionally, the particular importance of the ground control points located in those areas for the accuracy of the triangulation should not be forgotten. Generally, three overlapping areas are used for the location of the points, but in specific cases it does not work, and the points located in two overlapping areas (e.g. areas covered by forest or water) should be used. In that case, it is necessary to know the affect on the accuracy of the whole aerial triangulation or further processing of the photos (Liba et al., 2009). The aim of the research is based on the description of different principles of external aerial triangulation and on determining its effect on further processing. The above mentioned is the major aim of the present paper, mainly, due to the fact that the authors are not aware of any previous research of the kind.

Aerial triangulation, affine transformation, DTM, orientation parameters, PHOTOMOD system, TIN.

Introduction

In photography, as well as in many other fields, changes have taken place – digital installations are now used along with analogous technology (Hinz, 1999). These changes are reflected in many related fields, primarily in stereophotogrammetry, e.g., the process of orthophoto creation has changed. Earlier, a three-year period was needed to develop from the initial photograph captured to the completed orthophoto, whereas now it takes less than half a year, depending on the aerial cameras, the software, etc.

Analogous cameras (an ordinary photograph is obtained that needs scanning), and digital aerial cameras (which use matrix or strip sensors) are used for orthophoto creation (Hinz, 1999). The image obtained needs processing by a specific software programme.

Photogrammetric software programmes are fairly different and their usage mainly depends on input data, on experience and skills, on the existing needs, and also on software cost. Producers mostly tend to stick to their once acquired software product, because of the lack of information on alternative systems or, because the inquiries into the precision and accuracy possibilities of new programmes might be time consuming. Additionally, there may exist various aspects affecting the accuracy of the final product (Melnikova, 2005). Various principles of external aerial triangulation may serve as an example.

The present research work analyses the effect of different principles of external aerial triangulation on the whole process of triangulation. Photogrammetric software PHOTOMOD is used for aerial triangulation. This software is produced in Russia and is currently used in more than 50 countries (Figure 1).

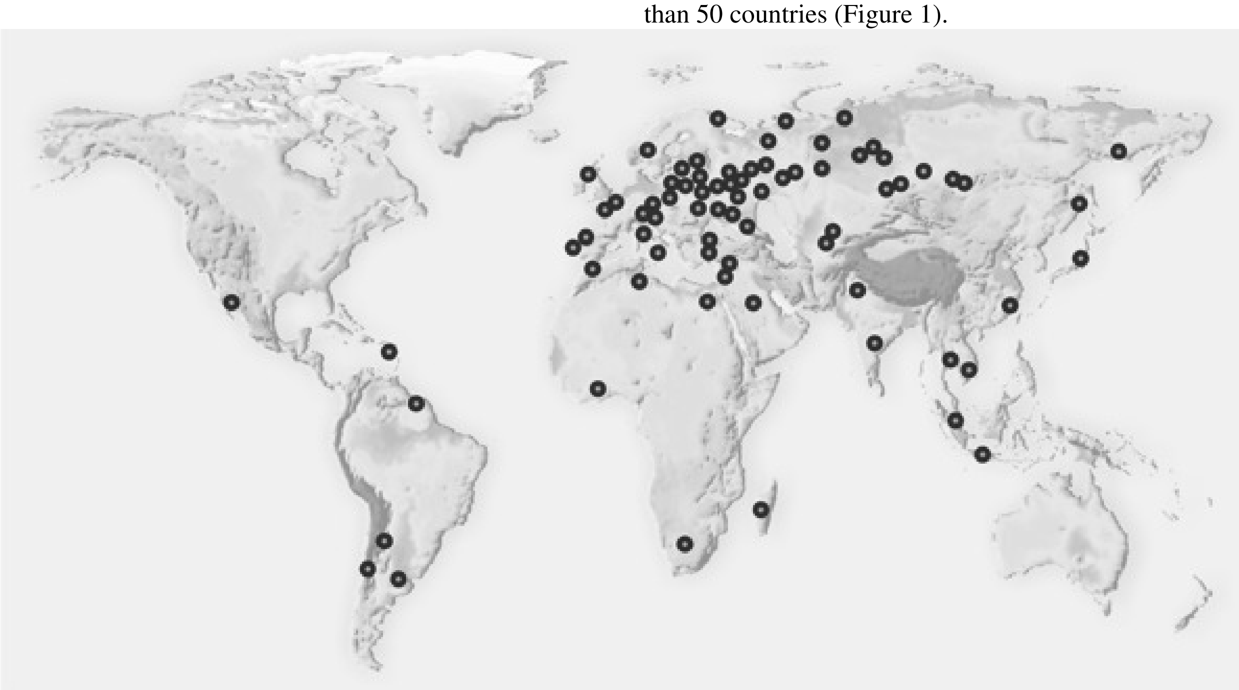

Fig. 1. Usage of the photogrammetric software Photomod. (*Пользователи*, 2010)

The software enables orthophotograph creation from the initial photographed image to the end product, using different modules (PHOTOMOD AT, Solver, DTM and Mosaic). PHOTOMOD system enables the processing of both analogue and digital aerial photographs (Melnikova, 2005).

The focus of the research is aerial photos covering the area, where it is complicated to find and measure the necessary ground control points (e.g. areas covered by forest or water). Generally, the ground control points for the aerial triangulation should be located in three overlapping areas, but if it is complicated (like in the areas mentioned before) and only two overlapping areas can be used for ground control points, then it is essential to realize the resulting effect on further processing of the photo and the accuracy of aerial triangulation.

Materials and methodology

The aim of the research is based on the description of different principles of external aerial triangulation and on determining its effect on further processing. Two projects with the same area were used for the research. There were 12 analogue aerial photographs in central projection, of the City of Tartu for both projects. Aerial photographs were organized in 4 strips, each strip containing 6 photos. The photographs were captured by a low flying aircraft (1532 m, focal length 153,190 mm) by a Swiss company on October 2, 2000; RC 20 camera nd the optical type of camera 15/4 UAGA-P, with the aperture of 4,0 were used, and the photographs were scanned with DSW200 scanner.

For the external aerial triangulation, 6 ground control points were used in both projects. Points were measured with Real Time GPS in summer 2009. The ground control points were located only in two overlapping areas for the first project and in three overlapping areas for the second project.

Aerial Triangulation (AT) and Block Adjustment (Solver)

There exist two different successive modules in PHOTOMOD system for aerial triangulation: AT (Aerial Triangulation) and Solver (Block Adjustment) modules. AT includes defining interior orientation, external orientation and relative orientation (Киселева, 2009). In both projects the interior orientation procedure determined the position and the orientation of the film coordinate system relative to the coordinate system of the digital image. Besides, during interior orientation, the parameters describing a systematic film distortion were found (PHOTOMOD Solver, 2009). The parameters defined in the process of interior orientation were used to transform the measured image point coordinates from the digital image coordinate system to the film coordinate system. Five types of transformation from the digital image coordinate system to the film coordinate system are implemented in the PHOTOMOD AT module (PHOTOMOD AT, 2009).

In the process of interior orientation, coordinates of fiducial marks were measured. Transformation of fiducial marks depends on the initial fiducial marks of the selected data (at inserting camera data). Affine transformation (1) was selected.

The affine transformation was described by the following equation:

$$x = ao + a1\ xc + a2\ yc$$
$$y = bo + b1\ xc + b2\ yc\,, \qquad (1)$$

where x, y - coordinates of a point in the film coordinate system;
ai, bi - parameters of transformation;
xc, yc - coordinates of a point in the digital image coordinate system. (PHOTOMOD AT, 2009)

Relative orientation included addition of the points into the overlapping areas between strips and adjacent images, at least 6 points in each.

For external orientation, 6 various coordinates (x, y, z) of ground control points were determined in L-Est'97 coordinate system for both projects, according to the principles described before. After the input of the points to the corresponding catalogue, their location was determined on the photos. This is one of the main aspects defining orthophoto mosaic quality. The location of the point should be cognitive in the photo, therefore, the sketches from the point location in nature, are exceptionally useful. Road crossings or axes cannot be used for ground control point locations, because they are not reliable enough, especially if the photos and point measurements were made some time ago (Melnikova, 2005).

For both projects the ground control points were selected over the whole area and located in cognitive places like corners of parking grounds or corners of road curbstones (Figure 2).

Locations of ground control points for both projects in L-Est'97 coordinate system are shown in figures 3 and 4.

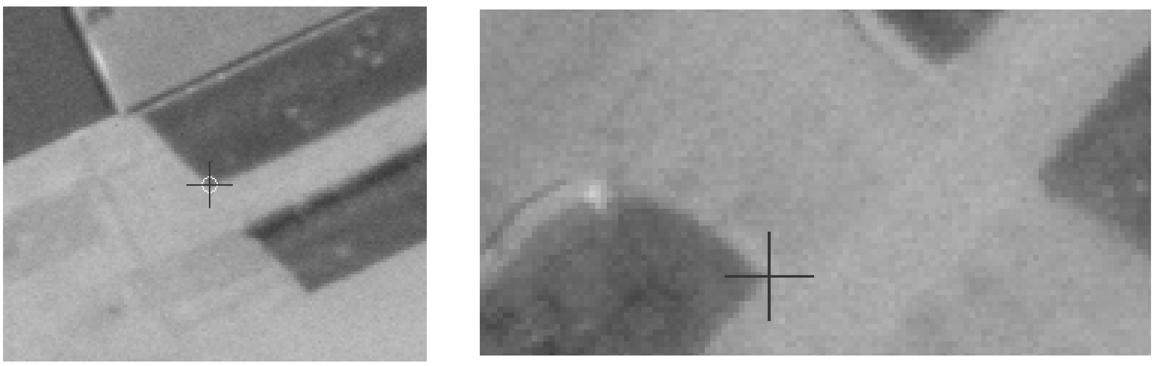

Fig. 2. Exceptionally good locations of cognitive points in aerial photo

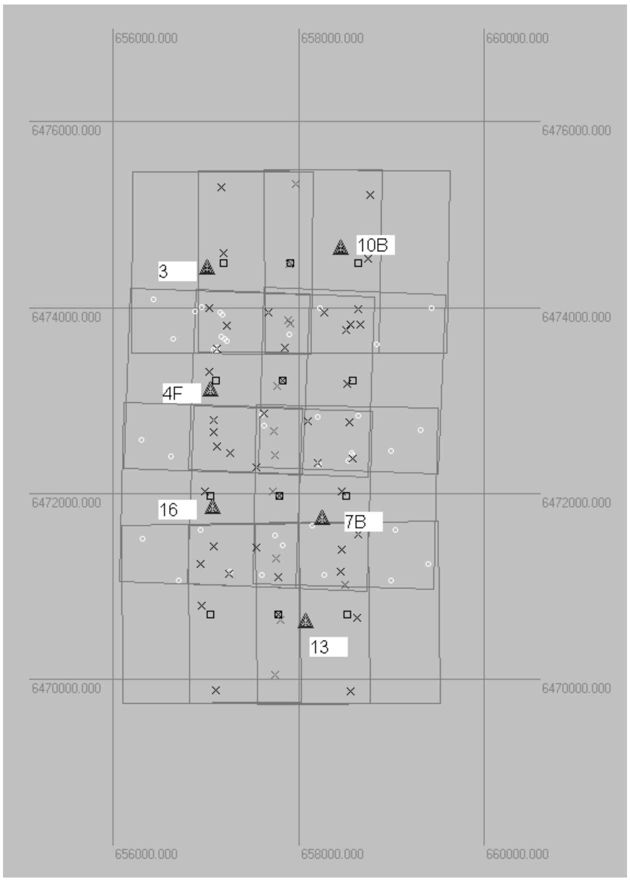

Fig. 3. Location of ground control points in the two overlapping areas

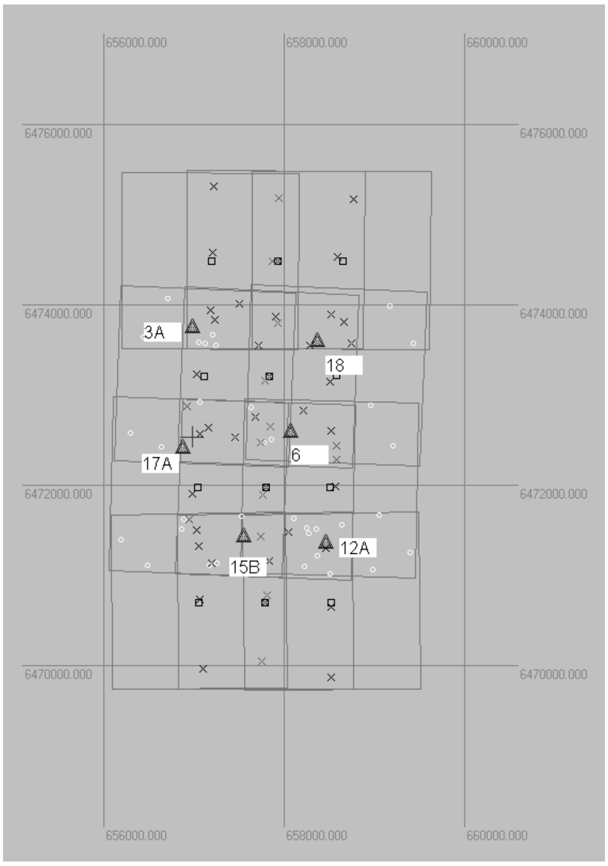

Fig. 4. Location of ground control points in the three overlapping areas

Having completed the block adjustment, exterior orientation parameters (alpha, omega, and kappa), as well as residuals of ground control points and tie points, which had to be smaller than 1 pixel in size (0,2m), were computed for each photograph. The result was a block of imagery in geodetic coordinated system. Different methods were applied for block adjustment in both projects. The first one is independent strips model method, which is basically used to eliminate the gross errors, such as wrong coordinate values of control points, incorrect measurements of tie points, etc. The second method is an independent stereo-pair method, used to improve the accuracy, achieved by independent strips method (Киселева, 2009). The latter method was used for the analysis.

Block Processing

The further research involved the development of the 3D terrain model for each stereo pair, using creation and edition of TIN (Triangulated Irregular Network) in both projects (PHOTOMOD DTM, 2009).

Creation and editing of TIN (TIN - vector model covering modeling surface with spatial elementary triangles) used Delaunay algorithm (Triangulated Irregular Network, 2005).

Delaunay triangulation is a proximal method that conforms to the requirement that a circle drawn through three nodes of a triangle will contain no other node (Figure 5).

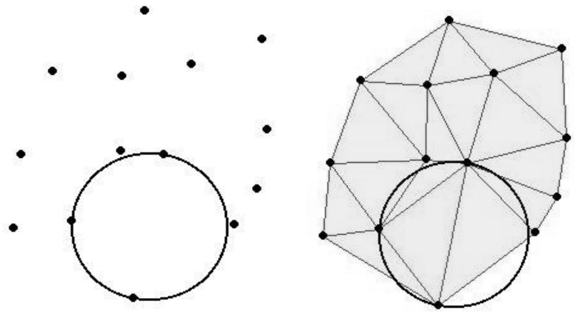

Fig. 5. Delaunay algorithm (Triangulated Irregular Network, 2005)

Delaunay triangulation has several advantages over other triangulation methods:

- The triangles are as equiangular as possible, this reduces potential numerical precision problems created by long skinny triangles;
- Any point on the surface is as close as to the node as possible;
- The triangulation is independent of the sequence in which the points are processed. (Triangulated Irregular Network, 2005).

The most frequently used TIN type is the Adaptive model, recommended to process large homogeneous or smooth images as well as those depicting water areas. The Adaptive model was created by calculating coordinates of TIN nodes (nodes in the grid) automatically by the correlator (PHOTOMOD DTM, 2009). This TIN type was used in the presented work and shown in figure 6.

In both projects the obtained DTM (Digital Terrain Model) (Figure 7) needs improving.

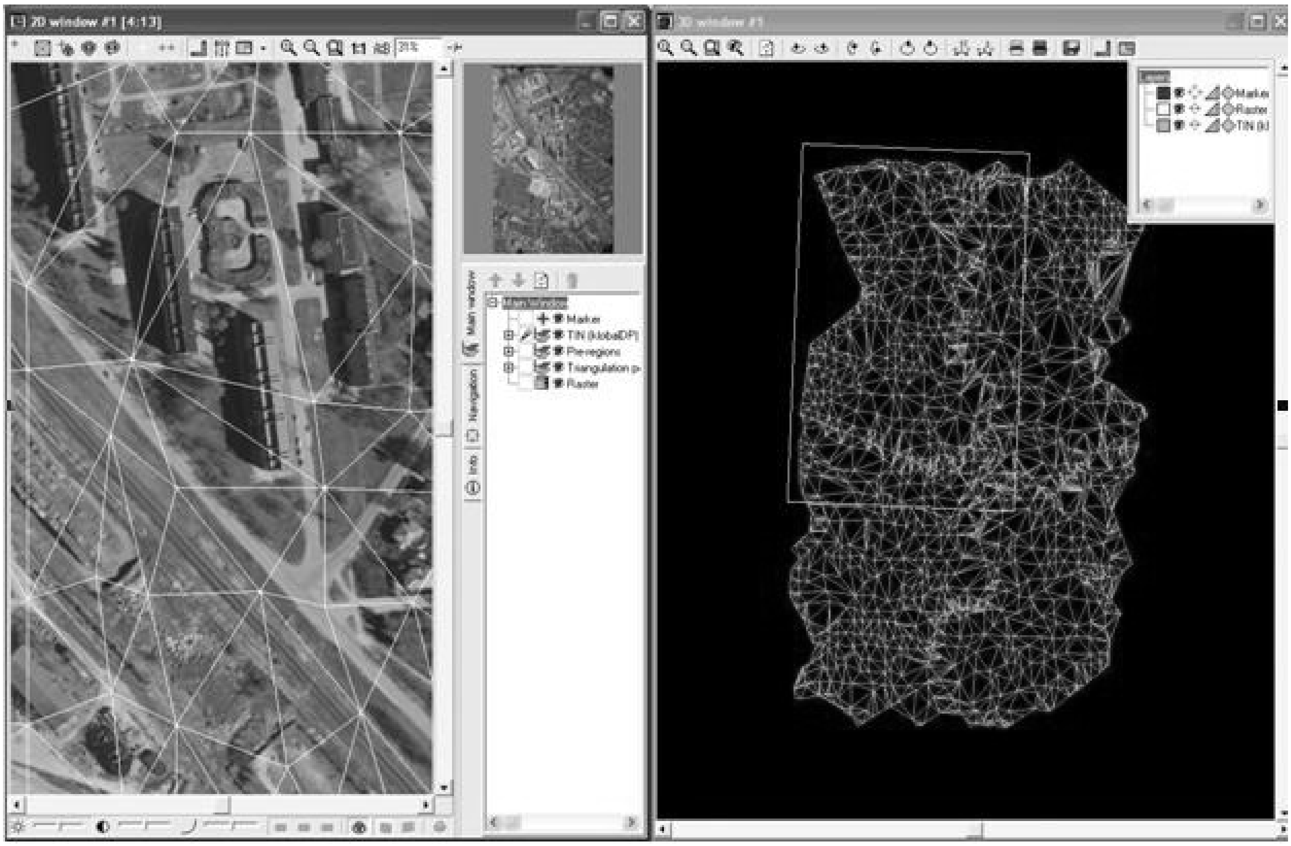

Fig. 6. Example of Adaptive TIN

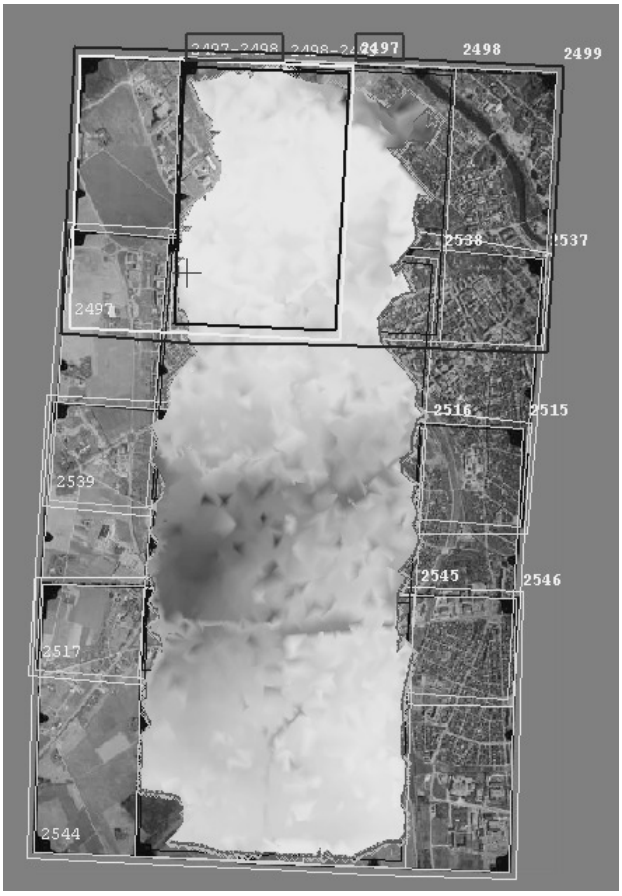

Fig. 7. 3D not improved model

Analysis

The results of the first project are shown in table 1, where X, Y, Z – are coordinates, calculated from the model; Xm, Ym, Zm – display coordinate value calculated from the all models; Xg, Yg, Zg – ground control points coordinates.

Some of the residuals (marked *) fail to meet the assumption that all the residuals are supposed to be smaller than 1 pixel in size (0,2 m), and mean root square errors of two points are bigger (p 10 B – 0,234 m and p3 0,414 m), and the both points are located on the first strip - all this all can affect the whole block.

The results of the second project are shown in Table 2.

Table 1. Ground control points residuals and mean root square errors for the first project

N	X-Xg (m)	Y-Yg (m)	Z-Zg (m)	Exy (m)
	0.200	0.200	0.200	0.200
10B	-0.200	0.122	0.120	0.234*
13	0.055	0.087	-0.156	0.103
16	-0.112	-0.017	-0.010	0.113
3	0.390*	-0.139	-0.128	0.414*
4F	0.084	-0.091	0.047	0.124
7B	-0.033	-0.033	0.102	0.047
mean absolute:	0.146	0.082	0.094	0.172
RMS:	0.190	0.093	0.106	0.211*
maximum:	0.390*	0.139	0.156	0.414*

Table 2. Ground control points residuals and mean root square errors for the second project

N	X-Xg	Y-Yg	Z-Zg	Exy (m)
	0.200	0.200	0.200	0.200
12A	0.055	-0.023	0.038	0.059
15B	-0.061	0.077	-0.064	0.098
17A	-0.015	-0.076	-0.022	0.078
18	-0.025	-0.058	-0.085	0.063
3A	0.070	0.081	0.046	0.107
6	-0.024	-0.000	0.088	0.024
mean absolute:	0.042	0.052	0.057	0.071
RMS:	0.047	0.061	0.062	0.077
maximum:	0.070	0.081	0.088	0.107

Results of the second project show that residuals of all points are in permitted dimension, which means they are smaller than one pixel in size.

Comparison of both projects brings to the conclusion that selection of ground control points in three overlapping areas improves the accuracy.

Summary and conclusions

Aerial triangulation comprises internal, relative, and external orientation (Liba, 2005). There are two different principles in external orientation, differing in location of ground control points in overlapping areas on aerial photos. Given research work investigates the affect of various principles of external orientation on the overall triangulation accuracy.

There were two different projects used for the research work. Overall triangulation was made for both projects. However, ground control points located in only two overlapping areas were used for the first project and those located in three overlapping areas were used for the second one.

Analysis and comparison of two projects show that two of six points in two overlapping areas were larger than required. The mean root square error of point 10 B was 0,234 meters and of point 3 - 0,414 meters. All points were of permitted size in three overlapping areas. This brings to the statement that selection of ground control points in three overlapping areas is better for aerial triangulation. Assuming the principles of the aerial triangulation, where interdependent ground control points are used for the block adjustment, this affects the accuracy of final block and, consequently, the accuracy of the orthophoto mosaic. One of the possible focuses of further research may be investigation of the affect of various principles of external aerial triangulation on the overall orthophoto mosaic accuracy.

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Skirtingų išorinės orientacijos metodų įtaka bendram trianguliacijos tikslumui

Santrauka

Viena iš svarbiausių fotogrametrijos dalių yra mozaikinio ortofotoplano gamyba ir jo tikslumas. Aerotrianguliacija yra viena iš mozaikinio ortofotoplano gamybos ir tikslumo sudėtinių dalių. Pasaulyje yra naudojama įvairi programinė įranga šiuos ortofotoplanams gaminti. Skirtingos programos siūlo skirtingus sprendinius ir galimybes. Jei nuotraukos darytos naudojant matricos jutiklius, ji turi dvi arba tris persidengiančias zonas, be to, kontroliniai taškai žemėje šiose zonose yra labai svarbūs trianguliacijos tikslumui. Dažniausiai naudojamos trys persidengiančios zonos kontroliniams taškams nustatyti, tačiau kartais tenka naudoti kontrolinius taškus tik iš dviejų zonų (pvz., jei plotai padengti miškais ar vandens telkiniais). Tokiais atvejais svarbu žinoti, kaip tai paveiks visą aerofototrianguliacijos tikslumą ar tolesnį nuotraukų apdorojimą. Tyrimo tikslas – išnagrinėti skirtingus išorinės aerotrianguliacijos metodus ir jų poveikį nuotraukas apdorojant ir jų tikslumui.

Aerotrianguliacija, transformacija, DTM, orientavimosi parametrai, PHOTOMOD sistema, TIN

Ина Ярве, Наталия Либа

Влияние различных принципов внешней ориентации на общую точность триангуляции

Резюме

Одна из важнейших задач фотограметрии – производство мозаичного ортофотоплана и его точность, неотъемлемой частью которых является аэротриангуляция. Для производства ортофотопланов в мире применяется разное программное обеспечение. Различные программы предлагают разные решения и возможности. В случае если фотографии сделаны с использованием матричного сенсора, они будут иметь две или три перекрывающиеся зоны. Кроме того, опорные контрольные точки, расположенные в этих зонах, имеют особую важность для точности триангуляции. Как правило, для контрольных точек используются три перекрывающиеся зоны, но в особых случаях приходится использовать точки из двух перекрывающихся зон (например, если площади покрыты лесом или водоемами). В таких случаях важно знать, как это отразится на всей точности аэротриангуляции или дальнейшей обработке фотографий. Цель представленного исследования – рассмотреть различные принципы внешней аэротриангуляции, описать их влияние на дальнейшую обработку фотографий и их точность.

Аэротриангуляция, трансформация, цифровая модель рельефа, параметры ориентации, система PHOTOMOD, модель TIN.

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