Making Orthophotomosaic about Tartu City with PHOTOMOD Program and Its Geometrical Quality

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Key words: orthophotomosaic, aerial triangulation, block of imagery, orientation, orientation parameters, DTM (Digital Terrain Model), geometrical quality, PHOTOMOD system.

ABSTRACT

Great changes took place in stereophotogrammetry during the previous century – along with analog technology, also digital installations are now used, specifically aerial cameras and photogrammetric systems. A multitude of photogrammetric digital systems on the market allow the end product to be created from initial images recorded, in a single photogrammetric workstation. Usage of these systems depends on input data, skills, financial capacity etc. It is impossible to detect the best system, but the quality of the end-production may be assessed. Therefore, the main aim of the current research work was the quality/accuracy assessment of an orthophotomosaic about Estonian city Tartu produced in PHOTOMOD. The software is currently used in more than 40 countries, in Estonia it had not been used before.

The investigation was conducted using ground control points, measured in the field and interactively on screen. After the measurements, the results were compared. The final product created in PHOTOMOD conformed to quality standards.

KOKKUVÕTE JA JÄRELDUSED

Uurimustöö käigus on tehtud ülevaade ühest spetsiifilisest fotogramm-meetrilisest tarkvarast PHOTOMOD, millega on valmistatud ja kontrollitud Tartu linnaosa ortofotomosaiik mõõtkavas 1: 2000. Arvestades mõõtkava täpsusega on valmistatud ortofotomosaiigi lubatav täpsus kuni 0,6 m. Kui võtta arvesse piksli suurus, mis on antud ortofotomosaiigi jaoks 0,177 m, siis täpsus peab olema kuni 0,45 m (2,5 piksli suurus). Ortofotomosaiigi keskmiseks ruutveaks saadi 0,181 m, mis on leitud veaga 0,043 m. Üle lubatava väärtuse ei olnud ühtegi punkti, kuid pisut suurema nihkega oli kaks punkti nr 4 (0,315 m) ja 9 (0,332 m). Põhjuseks võib tuua selle, et need punktid ei olnud nii täpselt tunnetatavad. Neljanda punkti puhul võis häirivaks faktoriks olla äärekivi vari, üheksanda puhul antud kohas äärekivi hävinemine. Kokkuvõtteks võib öelda, et valmistatud ortofotomosaiik vastas etteantud täpsusnõudele ja et antud programmiga on võimalik saavutada sobiva geomeetrilise kvaliteediga ortofotot. Lähimas perspektiivis on plaanis uurida veel ka kõrguslikku aspekti ja ortofotode täpsust, mis on valmistatud kasutades digitaalset maatrikssensorit või ribasensorit ning kasutades teisi aerortriangulatsiooni lahendusi.

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1. INTRODUCTION

As in many other fields, changes have taken place in photography - along with analog technology, digital installations are now used. These changes are reflected in many related fields, primarily in stereophotogrammetry. For example, the process of orthophoto creation has changed. Earlier, a three-year period was needed from the initial photograph captured to the completed orthophoto, but now it takes less than half a year. It depends on the aerial cameras, the software we use, etc [Грошев, 2006]. Data processing from recording the data to the final product is shown in Fig. 1.

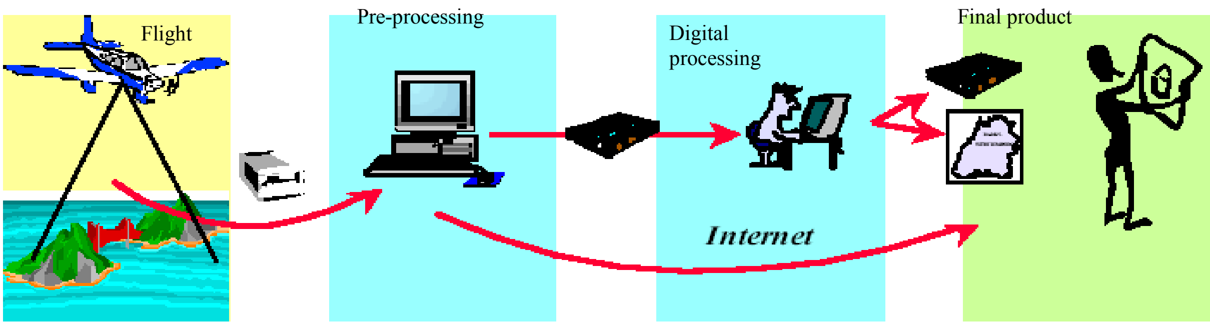

Fig 1. Data processing from recording the data to the final product [Hinz, 1999]

In recent decades, there have been advances in the use of digital aerial cameras. Although at the present time ordinary cameras and devices processing aerial photos directly (analogue or analytical stereo plotters), are still in use, digital processing of aerial photographs in photogrammetric digital systems is widespread. In Estonia, orthophotographs are made by both government agencies (Estonian Land Board, Estonian Map Centre Ltd, Estonian University of Life Sciences) and private enterprises (FMKart, VIVAL Metrica, EOMAP etc). They use analogue cameras (ordinary photograph obtained that needs scanning), and also digital aerial cameras (which use matrix or strip sensors) for orthophoto creation. The image obtained needs a specific software programme for processing.

Photogrammetric software programmes are very different and usage of them depends mostly on input data, on our practice and skills, on our needs, and also on cost of software. 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.

The present research work gives an overview of one of the photogrammetric software programmes PHOTOMOD, which was produced in Russia and is currently used in more than 40 countries. The paper analyses the quality and precision of the product created with PHOTOMOD. The software enables orthophotograph creation from the initial photographed image to the end product, using different modules. The Department of Geomatics at the Estonian University of Life Sciences bought the PHOTOMOD software programme for teaching purposes: due to that this software was used in our investigation.

PHOTOMOD system enables the processing of both analogue and digital aerial photographs. Similar research has been carried out several times in Russia, with the aim of studying the quality of the final product M 1:10000. The present research studies the product M 1:2000. [Racurs, 2007]

2. MATERIALS AND METHODOLOGY

The aim of the research was geometric quality control, using ground control points, of one specific orthophotomosaic M 1:2000, created with stereophotogrammetric programme PHOTOMOD.

12 analogue aerial photographs in central projection, of the City of Tartu, were used. Aerial photographs were organized in 2 strips, both strip containing 6 photos. Photographs were captured by low flying aircraft (1532 m, focal length 153,190 mm) by a Swiss company on October 2, 2000; used camera RC 20, the optical type of camera 15/4 UAGA-P, aperture 4,0, scanner DSW200.

There are 4 main stages in PHOTOMOD system (block formation, aerial triangulation, block adjustment and block processing).

2.1. Aerial Triangulation (AT) and Block Adjustment

AT included defining interior orientation, exterior orientation and relative orientation. 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. 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.

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

The affine transformation [Racurs, 2003.AT] was described by the following equation:

$$x = a_o + a_1 x_c + a_2 y_c$$
$$y = b_o + b_1 x_c + b_2 y_c , \qquad (1)$$

where x,y - coordinates of a point in the film coordinate system;
a_i, b_i - parameters of transformation;
x_c,y_c - coordinates of a point in the digital image coordinate system.

For exterior orientation, coordinates of 7 ground control points were determined.

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

After block adjustment, exterior orientation parameters for each photograph (alpha, omega, and kappa) were computed, as well as ground control points' residuals and tie points' residuals [Racurs, 2003. Solver]. The result was a block of imagery in geodetic coordinated system.

After adjustment, ground control points' and tie points' residuals were less than 1 pixel size.

2.2. Block Processing

Block processing included creation of a 3D terrain model for each stereo pair model, using creation and edition of TIN (Triangulated Irregular Network), and eventually of an orthophotomosaic.

In the present paper, for creating and editing TIN (TIN - vector model covering modeling surface with spatial elementary triangles), Delaunay algorithm [Triangulated Irregular Network, 2005] was used.

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.
Delaunay triangulation has several advantages over other triangulation methods:
- The triangles are as equi-angular as possible, thus reducing potential numerical precision problems created by long skinny triangles;
- Ensures that any point on the surface is as close as to a node as possible;
- The triangulation is independent of the sequence in which the points are processed

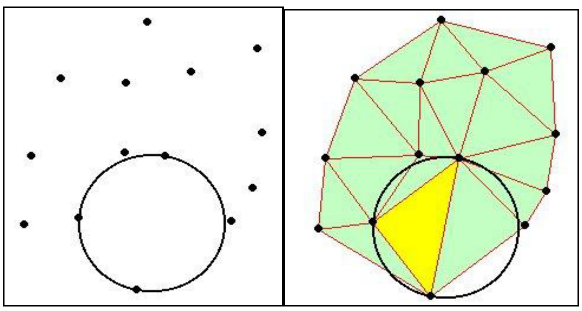

Fig 2. Delaunay algorithm

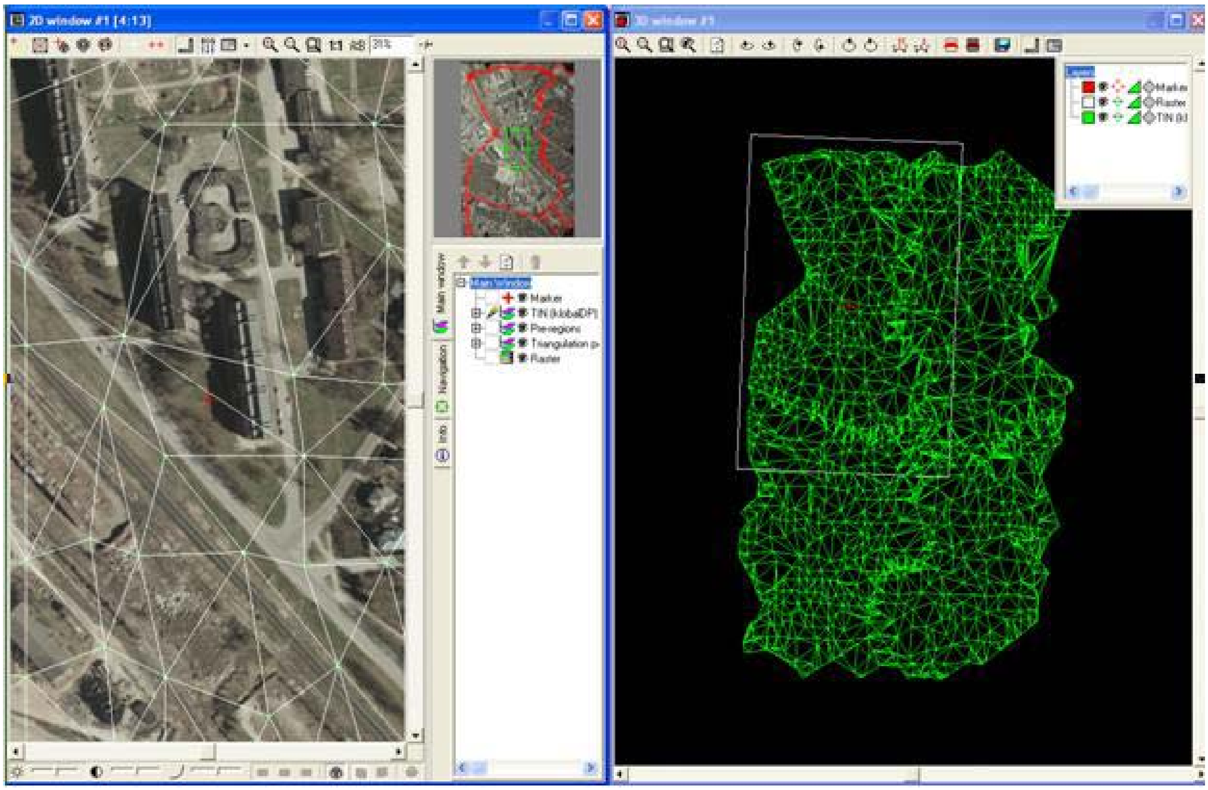

Fig 3. Example of Adaptive TIN

The most frequently used TIN type is the Adaptive model recommended to process images having large homogeneous or smooth parts and water areas. This type was used in the present work.

The Adaptive model [Racurs, 2003. DTM] was created by calculating TIN nodes coordinates (in the grid nodes) automatically by the correlator (Fig 3). Height of TIN nodes relative to the surface was controlled and improved by TIN. We got DTM (Digital Terrain Model) as a result (Fig. 4).

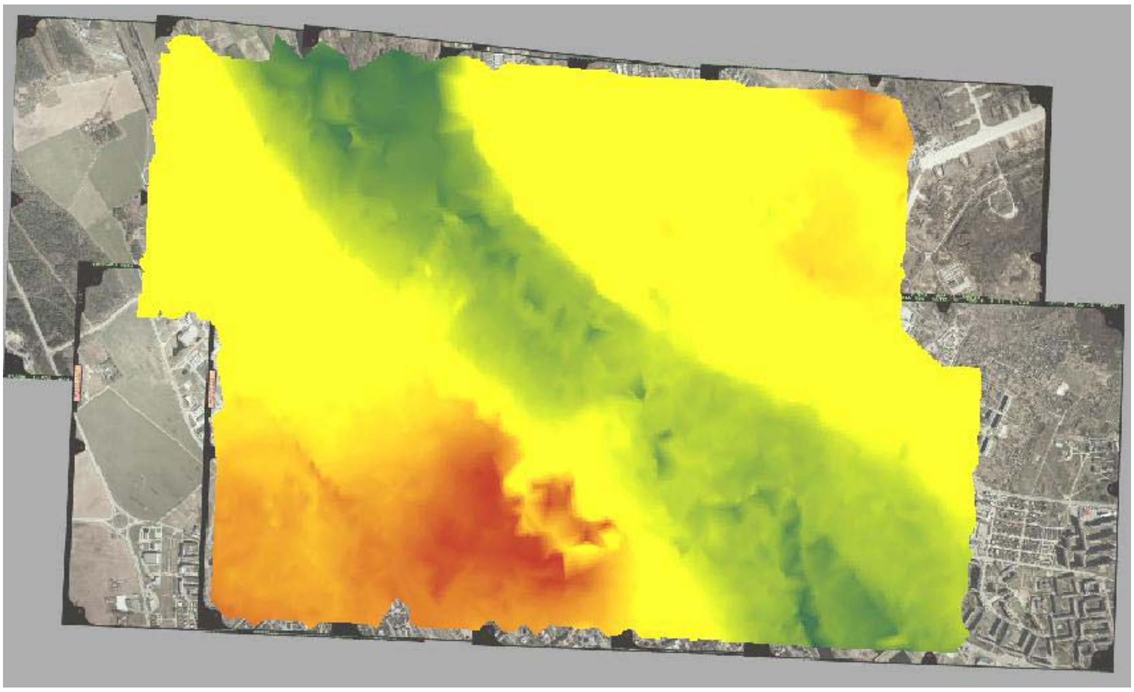

Fig 4. 3D improved model

2.3 Interactive and Field Measurements

Using 4 main stages of PHOTOMOD system, a digital orthophotomosaic was made of the City of Tartu, with surface area 15 km^2, coordinated system L-Est´92, pixel size 0,177 m and scale 1:2000 [Melnikova, 2005].

Geometrical quality of the orthophotomosaic was estimated by the following methodology [Liba, Veermets, 2002]:

1) planning the location of ground control points;
2) measuring the ground control points on the terrain, data processing;
3) interactive measuring of ground control points , data processing;
4) data comparison, geometrical quality calculation, evaluation.

In estimating the geometrical accuracy, 9 ground control points' coordinates measured with real-time GPS Trimble 5800 were used. Trimble Geomatics Office software (for calculation of field measurement coordinates), software PHOTOMOD (for measuring control points in orthophotomosaic) and Microsoft Excel (for measurement data processing) were used.

The basis for the number of control points used in the present paper is the number of ground points required for quality assessment of a digital orthophoto: the number of control points depends on the scale of the orthophotomap. Recommended is 9 control points for map scale 1:10000 and for larger scale; for a smaller scale map, a greater number of points is necessary [Kargaja, 2004].

Pursuant to the above requirement, the number of points used was 9, separating the orthophotomosaic to 3x3 notional grids, with 1 control point in each square. The following parameters were followed in the selection of control points:

1) control points should be highly cognizable both on the mosaic and on the terrain;
2) opening of horizon should be more than 20º;
3) location of control points should be on area of three overlapping.

According to the standard requirements for interactive measurements, measurement deviation should not exceed 0,177 m (one pixel size). In case of deviation, the measurements were repeated on the corresponding points.

Interactive measurements on the screen were concluded twice, to increase reliability. Each measurement was performed, using two different measurement methods:

1) *One point measurement series* – one point was measured continuously in three different increase steps: after that the next point was measured.
2) *Nine points' measurement series* – nine points were measured continuously in one increase step; the orthophotomosaic was increased to the next step and the measurement of the 9 points was repeated, etc.

Deviations of interactive measurements in one point measuring series and all points measuring series were relatively small: 0,05 and 0,07 meters correspondingly. Also, the mean root square errors for the interactive measurements were small: 0,05 for one measuring series and 0,08 for other series. Mean coordinates from both series were calculated, the result was considered to be the final coordinates for the measured points.

3. CALCULATION ACCURACY

Mean root square error (RMSE) for the orthophotomosaic, using the Gauss formula [Randjärv, 1997] and x and y coordinates, was calculated. Also, the dislocation of each point was calculated and their direction was estimated (Fig 5 and table 1).

Minimum difference between GPS and the orthophotomosaic coordinates in x-direction was 0,000 and in y-direction 0,020 m. Maximum difference was 0,179 and 0,294 m correspondingly. The measurements showed that differences were slightly bigger in y-direction, but the calculation doesn't show any systematic error.
The mean root square error of the orthophotomosaic was 0,181m, which in turn was computed with RMSE 0,043 m.

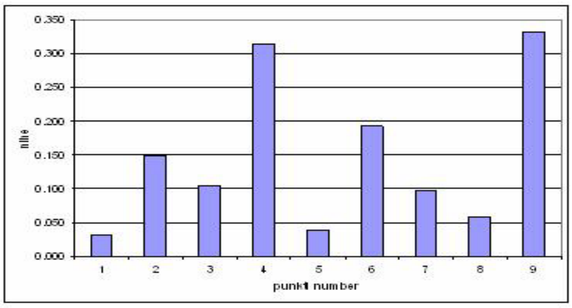

Fig 5. Differences in meters between measured points from GPS and orthophotomosaic

Table 1. Calculation of geometrical accuracy of an orthophotomosaic (units in meters)

Point no	GPS-coordinates		Mean coordinates from orthophotomosaic		Difference		Squared difference		Sum	Dislocation	Direction of dislocation
	X	Y	X	Y	ΔX	ΔY	$ΔX^2$	$ΔY^2$	$ΔY^2+ΔX^2$		
1	6476509.567	657307.368	6476509.548	657307.342	-0.019	-0.026	0.000	0.001	0.001	0.032	SW
2	6476047.249	658842.805	6476047.375	658842.726	0.126	-0.079	0.016	0.006	0.022	0.149	NW
...	...	...	...	...	...	...	...	...	...	...	...
9	6473829.358	660073.618	6473829.179	660073.338	-0.179	-0.280	0.032	0.078	0.110	0.332	SW
				Sum	0.115	-0.434	0.076	0.219	0.295		
				Min	0.000	0.020				0.032	
				Max	0.179	0.294				0.332	
				Mean	0.090	0.157				0.182	
				RMSE	Gauss formula		0.092	0.156	**0.181**		
				m_{io}	%		0.022	0.037	0.043		

4. SUMMARY AND CONCLUSIONS

In this paper, an overview of a specific photogrammetric software PHOTOMOD was given. PHOTOMOD was used to create and control the orthophotomosaic of the City of Tartu in scale 1:2000. Considering the accuracy of scale, the allowed accuracy of the orthophotomosaic was 0,6 m. Considering the pixel size (0,177 m for the given work), the accuracy should be 0,45 m (2,5 pixel size). The mean root square error of the orthophotomosaic was 0,0181 m, which in turn was computed using RMSE 0,043 m. No one point exceeded the allowed value, but 2 points had a slightly larger dislocation: point 4 (0,315 m) and 9 (0,332m). The reason may be that these points were not accurately cognizable. In point 4, a shadow on the curbstone could disturb, and in point 9, a demolished curbstone. Graphically, the difference between GPS and the orthophotmosaic coordinates is shown in Fig 6.

Fig 6. Location of control points and differences on the orthophotomosaic

In conclusion, it is possible to create orthophotomosaics conforming to quality standards, in suitable accuracy, with the PHOTOMOD software programme. In future, we are planning to study the aspect of heights and accuracy of an orthophoto created by digital sensor of matrix or, sensor of strip, and to use other solutions of aerial triangulation.

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