MAIN FEATURES OF ON-LINE TRIANGULATION ON DPS TSNIIGAiK

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ABSTRACT:

Digital photogrammetric station TSNIIGAiK (DPS-TS) is the basic mean for image processing in the State geodetic and cartographic service of Russia (Roscartografija). Now the total number of DPS-TS software installations exceeds 1300. So wide distribution of DPS-TS testifies it advantages basing on reliable algorithms and carefully thought over technology of photogrammetric works.
In the paper the main features of DPS-TS software with reference to on-line triangulation are shown. The following concerns them: interaction of several programs; the large palette of operations on repeating measurements, removing or adding of separate points, models, strips; the non-standard configuration of the block; an opportunity of creation of a free or oriented network of practically unlimited sizes; consecutive use of different methods of strip and block adjustment with the final stage of bundle adjustment; the mode of definition of unknown weights of the control data; detailed recording of computing process and representation the results in evident forms; use of conformal geodetic projections of three types (transverse, conic, stereographic) on any spheroid; well thought over structure of the information in a computer and the big speed of calculations.
All together the listed above and other features make on-line triangulation on DPS-TS a convenient, flexible, precise and productive technological process.

1. General information

Nowadays digital photogrammetric station (DPS) is the main technical instrument for creation and revision of digital topographic maps used on enterprises of State geodetic service of Russia (Roskartografia) and Ukraine (Ukrgeodezkartografia). The set of technological software have been developed in cooperation of TSNIGAIiK (Russia) and SSPE «Geosystem» (Ukraine) during last 10 years. The software automates all photogrammetric workflow including bundle adjustment, DTM/DEM creation, 3D-mapping and map publishing, orthophoto, etc. Main DPS features were described in materials of previous ISPRS congresses in Vienna and Amsterdam [1, 3].

This article shows some particular aspects in realization of online triangulation and bundle adjustment process on DPS.

2. Main features of triangulation on DPS

DPS software includes "Triada" program for triangulation measurements and "Photocom" rigorous bundle adjustment program. The software complex now combines triangulation measurements and control of results in the same technological process. These processes were separated in previous software releases that increased labor-intensiveness and decreased the quality.

On-line photo-triangulation technology consists of the following procedures and features:

- o Creating and processing blocks of any configuration and size;
- o Control of current results on measurement stage by adjustment of measured models and strips to check and locate the blunders;
- o Simultaneous visualization of six neighbor images for convenient tie point selection and measurements;
- o Automatic tie point transfer onto neighbor images;
- o Visual stereoscopic control of any point as along strip as between strips;
- o Rigorous bundle adjustment and visualization of residuals by vectors on all the block images;
- o Calculation of absolute orientation elements for further processing.

There are three main stages of the triangulation process on DPS: creation of block layout project, triangulation measurements and adjustment, merging of different blocks for their join adjustment. Below is a brief description of whole process.

3. Triangulation measurements

The main feature of measurements process is simultaneous visualization of two image triplets (from active strip and from strip below). The measurements program interface is shown on Picture 1. Measurements can be done in automatic mode with correlation or manually in mono or stereo modes. Stereo mode can be activated with previous or next image in the same strip as well as with lower image from strip below. Various shutter-glasses, polarized screens or stereoscope can be used for stereo visualization.
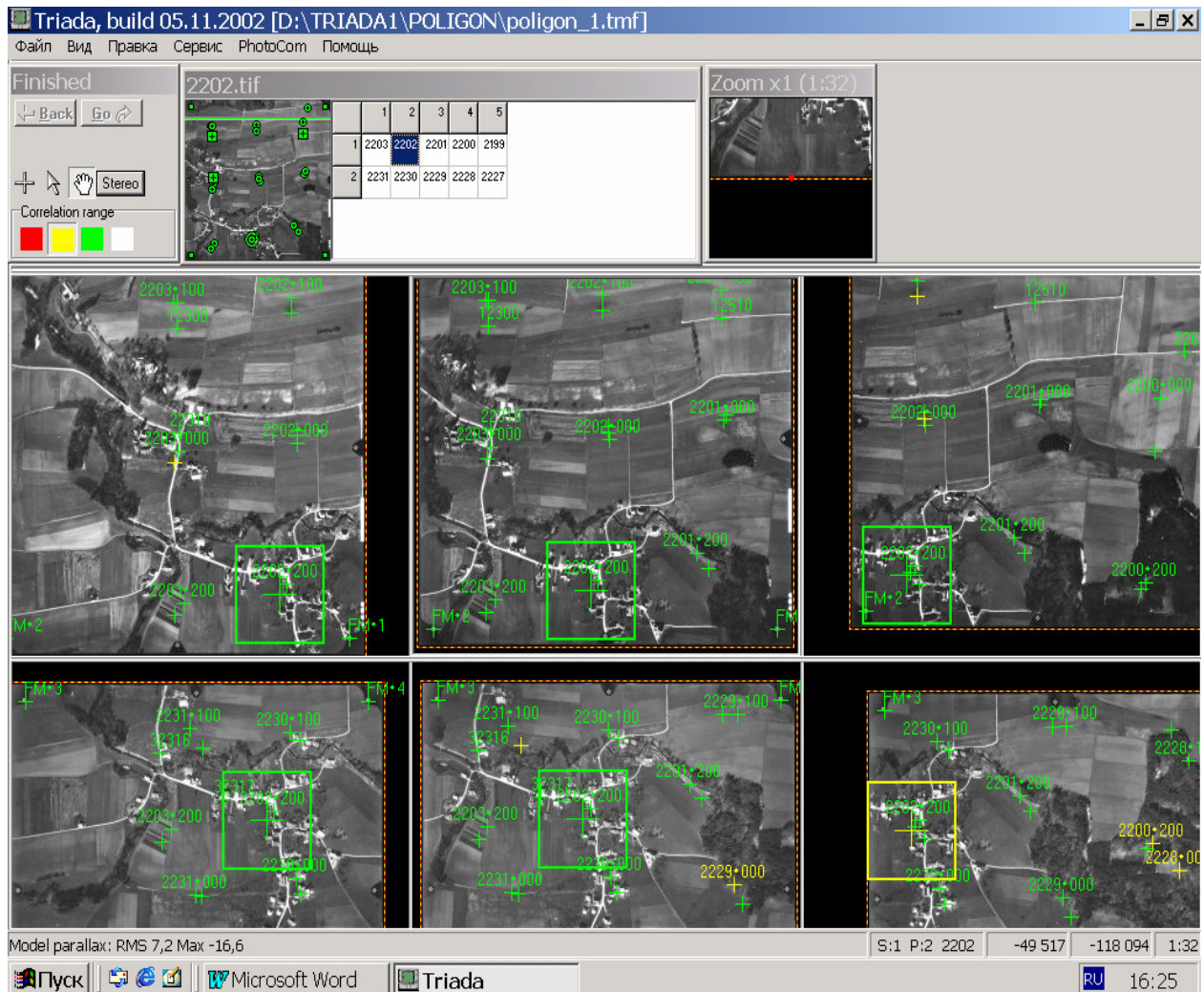
Picture 1. Interface of measurements program

There is a possibility to attach already measured strips to current block that is being measured. Program allows to merge different blocks in single network for their joint adjustment.

4. Control operations

All the technological cycle is saturated by various control operations. As far as performed measurements are enough for orientation of model, strip or block they are included in mathematical processing. Results of control operations are shown in a form that is convenient for analysis.

Special attention in the technology was placed to inner orientation process. The quality of fiducial marks' measurement effects on proper restore of projection rays and thus, on block adjustment accuracy. DPS software uses correlation method for automatic measurements of fiducial marks for whole block. Results of automatic measurement are controlled by coefficient of correlation and by residuals. Then program automatically asks for manual re-measurement of doubtful points.

There are two stages of tie points' accuracy control for blunder detection. On the first stage accuracy is controlled by parallaxes of calculated relative orientation and residuals for

tie points placed in triple overlap zone. It is recommended to place points in groups by two or more in every standard zone. That allows to detect blunders due to increasing of diagonal coefficients of matrix. When a blunder point is detected, it can be corrected repeatedly.

On the second stage (usually when strip measurement is finished) full adjustment for all measured strips is performed. **Photocom** on-line bundle adjustment engine is used for this. That is further development of well known **Photocom-32** adjustment complex that has been used for years in practical photogrammetric production on many Russian and Ukrainian enterprises. There three computation algorithms are available: checking of block conjunctions, interactive adjustment and automatic (batch) adjustment. Adjustment process consists of several stages that allows to detect and localize all the block defects and blunder points. Rigorous bundle adjustment is performed on the final computation stage using co-linearity conditions that gives more objective adjustment and control in comparison with other methods. A special self-calibration algorithm is used to determine the most probable residuals for every terrain point.

Adjustment uses least-squares method with weights assigned to all measured values. Minimization is performed by multiple solving and selection the best solution using statistic criteria.

5. Using coordinates of projection centers

Accumulated experience and special researches allow to say that using GPS data for adjustment creates practically non-deformated triangulation network provided that all systematic errors are taken into account. Ground points with known coordinates can be used to remove the systematic errors and to reach the maximum accuracy.

The amount of ground points for block can be reduced approximately by 3 times when GPS data for projection centers are available. It is recommended to have at least one ground point located in every strip overlay zone to compute individual systematic errors for different strips.

6. Creation of sketches

Sketches can be created for every photogrammetric point when bundle adjustment has been performed. The sketches are useful for absolute orientation of photos on analytical/analogical and instruments that sometimes still in use for mapping.

The sample of such sketch is shown on Picture 2.
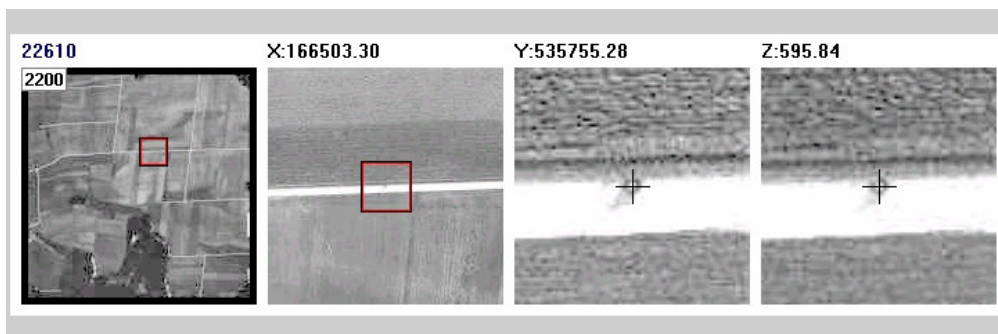
Picture 2. Sketch of a triangulation point

7. Joint adjustment of adjacent blocks

The **Photocom on-line** can perform adjustment of extensive triangulation networks with sizes that exceeds any practical need. But for parallel multi-user measurements big blocks are usually divided on smaller parts. Sometimes it requires some additional efforts for block junction and collecting points in overlapped zones.

DPS software has the possibility for joint adjustment of several sub-blocks. Such sub-block can also include cross-strips that are used widely for more rigid block model. As result of such adjustment, single coordinated block and total catalog of all adjusted points is created.

8. Data import and export

An external third party bundle adjustment can be used with DPS software. Thus interface with PAT-B and other popular adjustment programs is implemented. Triangulation measurements can be exported to various formats and orientation elements or adjusted coordinates can be imported as well.

9. Using in production

Samples of adjusted photogrammetric networks described below. Flight data and parameters of ground control points are shown in tables 1 and 2.

Block 1 is particular because of its non-standard configuration. First two strips consist of four models each and the rest of strips are much longer. Projection centers defined by GPS with 1.0 m accuracy were used for adjustment together with GCPs. Projection centers were missing for some of photos of internal strips. The sixth strip had photogrammetric break.
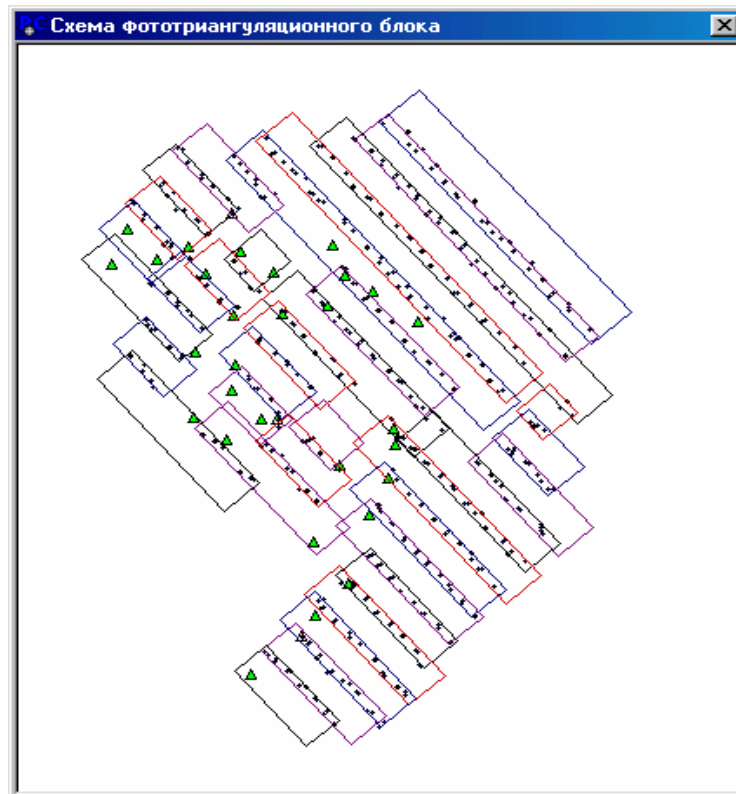
Figure 3. Non-standard configuration of the block

Table 1

Block number	Camera	Flight scale	Focal distance	Strips	Photos	Breaks	Flight direction
1	2	3	4	5	6	7	8
1	LMK	12800	152.440	12	233	+	W-E
2	RC-30	4300	305.117	3	24	-	W-E
3	LMK	9500	152.440	35	322	+	W-E
4	LMK	6000	153.478	3	19	-	S-N
5	RMK-TOP	10000	153.619	2	16	-	S-N
6	RMK	20000	152.850	29	395	+	N-S

The special feature of second block was numerous forest areas. GCPs were well distributed but measurement was quite difficult due to the forest areas.

Third block (Picture 3) has very complex configuration including several breaks. Ground control points and projection centers were used for adjustment. Although the block was computed successfully it is recommended to make deep analysis before deciding to use any non-standard configured blocks.

Small fourth block located in mountain area where ratio of terrain height to flight height reached 0.15.

Block number five is covered a flat area were maximum height difference is just 7 meters.

Adjustment results are shown in table 2. It estimates blocks' accuracy by residuals of co-linearity on ground and photogrammetric points.

Table 2

Block number	Block accuracy (RMS) by										Adjustment time (sec)	
	Co-linearity (microns)		Ground points (m)		Projection centers (m)		Photogram-metric points (m)		Control points (m)			
	X	Y	ms	mh	ms	mh	ms	mh	ms	mh	Free	GCPs
1	2	3	4	5	6	7	8	9	10	11	12	13
1	6	6	-	-	0.19	0.12	0.25	0.34	-	-	17	18
2	11	12	0.22	0.27	-	-	0.21	0.44	0.20	0.50	4	4
3	10	9	0.07	0.10	0.22	0.10	0.34	0.46	-	-	38	48
4	2	4	0.02	0.02	-	-	0.07	0.08	-	-	3	4
5	2	3	0.04	0.04	0.03	0.02	0.07	0.07	-	-	3	3
6	3	3	0.20	0.14	0.36	0.03	0.43	0.33	0.38	0.32	-	50

Block 3 has low accuracy GPS data (1.0 м), that is worse than accuracy of GCPs. It influenced the resulting accuracy. As shown in the table, computation speed is very high that gives the possibility of real-time quality control during measurement.

10. Conclusion

The real-time triangulation technology has been tested on many geodetic enterprises in Russia and Ukraine. In practical production became evident that block's RMS error does not exceed pixel size of block images. Maximum error is usually less than two pixels.
Developed technology eliminates the most time consuming process of physical marking of tie points and also removes the accuracy loss connected with such marking.
Real-time technology combining measurements, control and adjustment in single process produces reliable and error-free adjustment results for big and complicated blocks.

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