

# **DONETSKFOTO**

Software for Construction and Adjustment of Photogrammetric  
Networks

**for Windows 95/98/NT**

**version 4.2**

**User's Manual**

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<b>DONETSKFOTO</b>	<b>1</b>
<b>SOFTWARE FOR CONSTRUCTION AND ADJUSTMENT OF PHOTOGRAMMETRIC NETWORKS</b>	<b>1</b>
<b>1. OVERVIEW</b>	<b>3</b>
1.1 Introduction	3
1.2 Basic Principles	3
<b>2. CONTROL ELEMENTS</b>	<b>3</b>
2.1. Commands of main menu	3
2.1.1. Overview of main menu	3
2.1.2. <Block> menu	4
2.1.3. <Service> menu	5
2.1.4. <Calculation> menu	11
2.1.5. <Options> menu	11
2.1.6. <Result> menu	13
<b>3. PROGRAM CONTROL IN PACKET REGIME</b>	<b>14</b>
<b>4. PHOTOTRIANGULATION USING NAVIGATION MEASUREMENTS</b>	<b>15</b>
4.1. Conception of using navigation measurements	15
<b>FIG. 4.1</b>	<b>15</b>
4.2. Options of construction and adjustment of phototriangulation block	16
4.3. Adjustment results considering navigation measurements	16
4.4. Advantages of combined adjustment of navigation and photogrammetric measurements	18
<b>5. SOURCE DATA FORMATS</b>	<b>18</b>
5.1. Description of <Delta> data format	18
<b>PHOTOTRIANGULATION BLOCK &lt;NAME OF PROJECT&gt;</b>	<b>19</b>
5.2. Description of <PAT-B> data format	20
5.3. Description of <Standard> data format	22
<b>EXAMPLE OF DATA OF ONE STEREOPAIR IN &lt;STANDARD&gt; FORMAT</b>	<b>23</b>
<b>6. MODEL OF SOURCE DATA MISTAKES</b>	<b>23</b>
6.2 Calibration of elements of interior orientation of camera	24
6.2. Consideration of reduction between optical center of objective and camera station	24

# 1. Overview

## 1.1 Introduction

Stereopairs can be measured on stereocomparator, analytical photogrammetric device or digital photogrammetric station. The software allows to combine the measured stereopairs into the unified photogrammetric network and to adjust it using the rigorous method of bundles.

Rough mistakes are disclosed during the models combining. Systematic mistakes are excluded during the rigorous adjustment.

Use of satellite positional data for camera station is possible. Basic characteristics of the software are as follows:

- order of location of stereopairs in a source file is arbitrary;
- number of points on photo and stereopair is unlimited;
- photos with different focal distances are processed jointly;
- name of point contains up to 20 any symbols;
- number and location of tie points between stereopairs is arbitrary, i.e. theoretical sufficiency for models combining into a unified block is enough; for example, a stereopair can have only three tie points: one point per each adjacent model;
- number of ground control points is unlimited and must guarantee the geodetic orientation of a network, in case of insufficient number of ground control points a network is created in a free coordinate system.

## 1.2 Basic Principles

When you perform operations in DONETSKFOTO you use the standard conventions and principles of Windows.

Interface control is realized through the menu of forms on a screen with the help of a mouse.

Use mainly clicking or double clicking on the left mouse button.

Use the right mouse button only for closing some interface forms.

The usual order of construction and adjustment of phototriangulation network determines a sequence of menus' execution.

Results of calculation are saved in text files in DOS format with division into rows. It is possible to demonstrate results on a screen and to print them.

Program interface exists in Russian and in English.

Phototriangulation block processing implies the execution of the typical interface commands as follows:

- <Block/Open>;
- <Options>;
- <Calculation/Construction>;
- <Calculation/Adjustment>;
- <Result/Create Documents>;
- <Result/View/Print>;
- <Block/Close>;
- <Block/Store>;
- <Block/Exit>.

You can understand possible variants of the sequence with the help of description of the software control elements.

# 2. Control Elements

## 2.1. Commands of main menu

### 2.1.1. Overview of main menu

The main window contains the following menus:

The English version of the interface

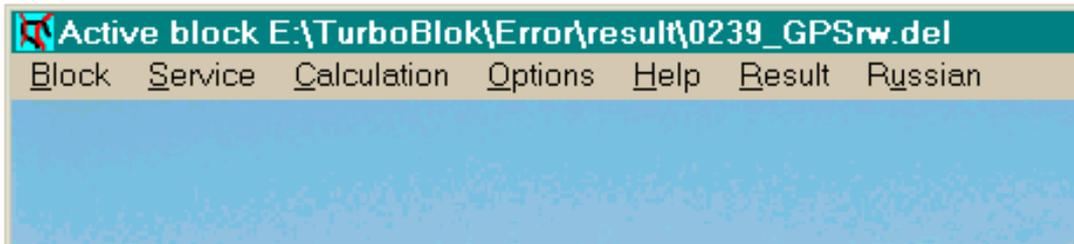


Fig. 2.1

The “Russian” (“English”) menu contains the commands for switching the interface from one language to another. If needed it is recommended to change a language before the start of block processing in order to have the same language for text information in calculation protocol and output tables.

The “Help” menu contains the commands for output the information about the program to a screen (About...).

### 2.1.2. <Block> menu

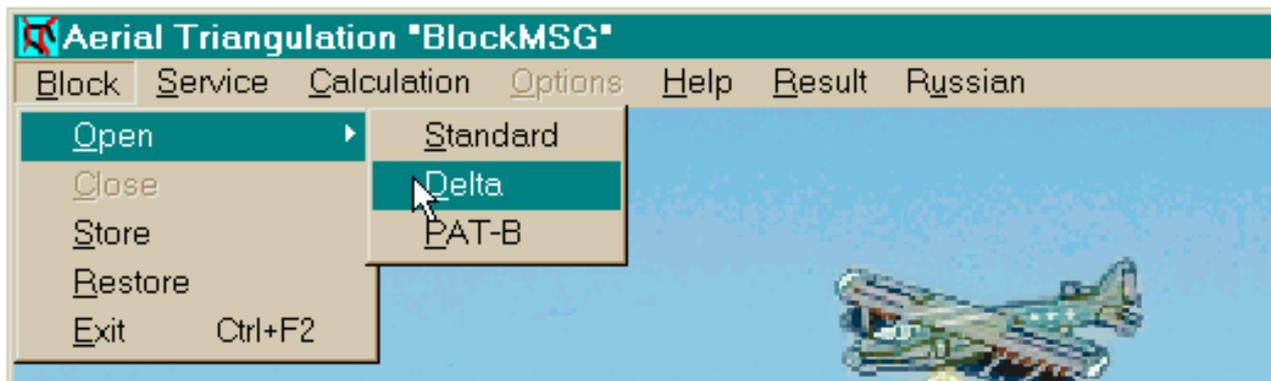


Fig. 2.2

#### 2.1.2.1. <Block/Open> command

After selection of this command, the standard Windows dialog box for files opening appears. It allows you to select a name and format of ASCII file with source data for phototriangulation network. After selection of a file, the program creates a new window, in which the selected file is downloaded.

It is possible to select a file with standard internal data format. Such files must have **\*.kmp** extension.

Files exported from the complex Digitals-Delta must have **\*.del** extension.

During data input in PAT-B format, the windows of dialog for selection of ASCII files open in succession:

- photogrammetric measurements of photos (as a rule, **\*.dat** extension);
- geodetic coordinates of ground control points (as a rule, **\*.txt** extension);
- navigation data with coordinates of camera stations (as a rule, **\*.txt** extension).

A file is transformed into standard internal format and is saved with the name of a source file but with **\*.kmp** extension. This file is a subject for further processing.

The most simple source file format is **\*.del** extension, in which stereopairs are located in arbitrary order. Chapter 5 contains the detailed description of data formats.

#### 2.1.2.2. <Block/Close> command

This command deletes all temporary files created for processing the phototriangulation block. The files of source data and calculation results remain. To continue or repeat the block calculations, it is necessary to open it again and to repeat processing. The program waits for opening a new block.

#### 2.1.2.3. <Block/Store> command

This command is used for interruption the block processing. In this case all temporary files and settings of program options are saved. The program waits for opening a new block.

#### 2.1.2.4. <Block/Restore> command

After selection of this command, the standard Windows dialog box for files opening appears. It allows you to select a file with \*.zms extension. A file with the name of needed phototriangulation block is selected. The program restores the settings, which were before the interruption of calculations, and is ready to further block processing.

### 2.1.2.5. <Block/Exit> (Ctrl+F2) command

This command unloads the program from the system. The program settings are saved. During the next start, it is ready to continue the block processing.

### 2.1.3. <Service> menu

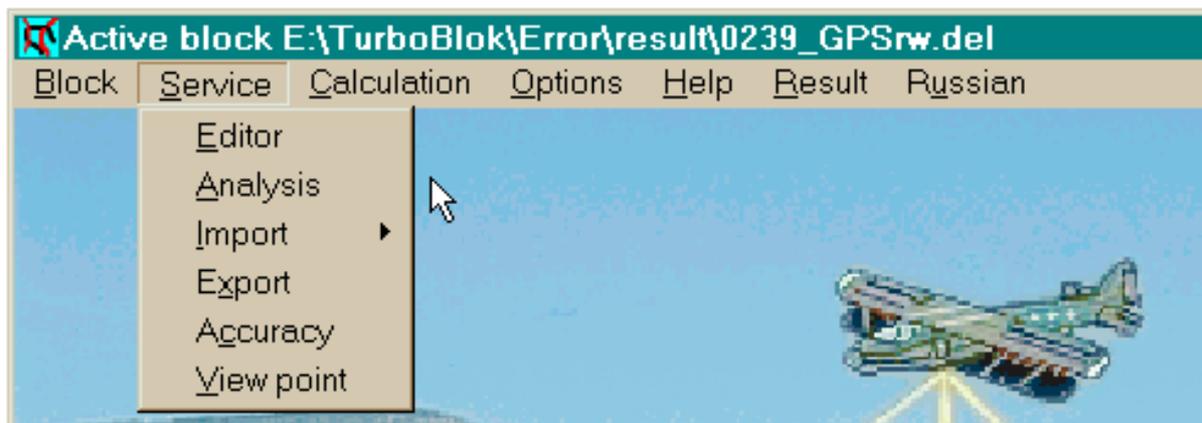


Fig. 2.3

#### 2.1.3.1. <Service/Editor> command

After selection of this command, the standard Windows dialog box for files opening appears. It allows you to select a standard file with source data with \*.kmp extension. A file with the name of needed phototriangulation block is selected. The editor window consisted of two parts opens (Fig. 2.4).

The left part contains editable data; the right part contains a list of stereopairs' numbers. Double clicking on the left mouse button allows you to obtain the needed stereopair.

Edited data can be saved in a file with the same name or with a new name. Use a file name without extension, the extension \*.kmp will be added automatically.

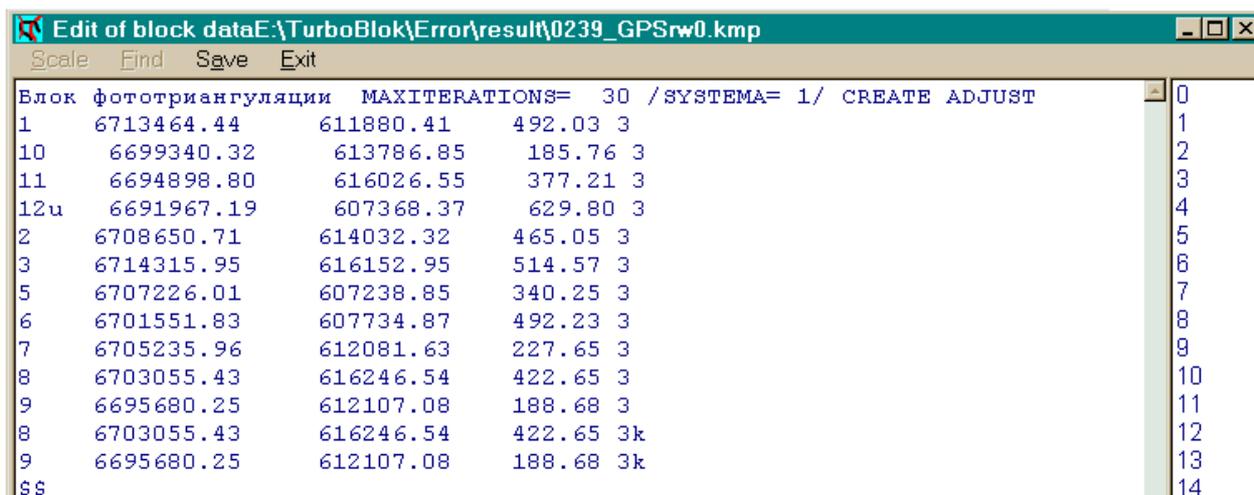


Fig. 2.4

#### 2.1.3.2. <Service/Analysis> command

The window of graphical analysis opens (Fig. 2.5). It demonstrates the results of construction of the phototriangulation network and allows you to visually evaluate the mistakes of models' combination.

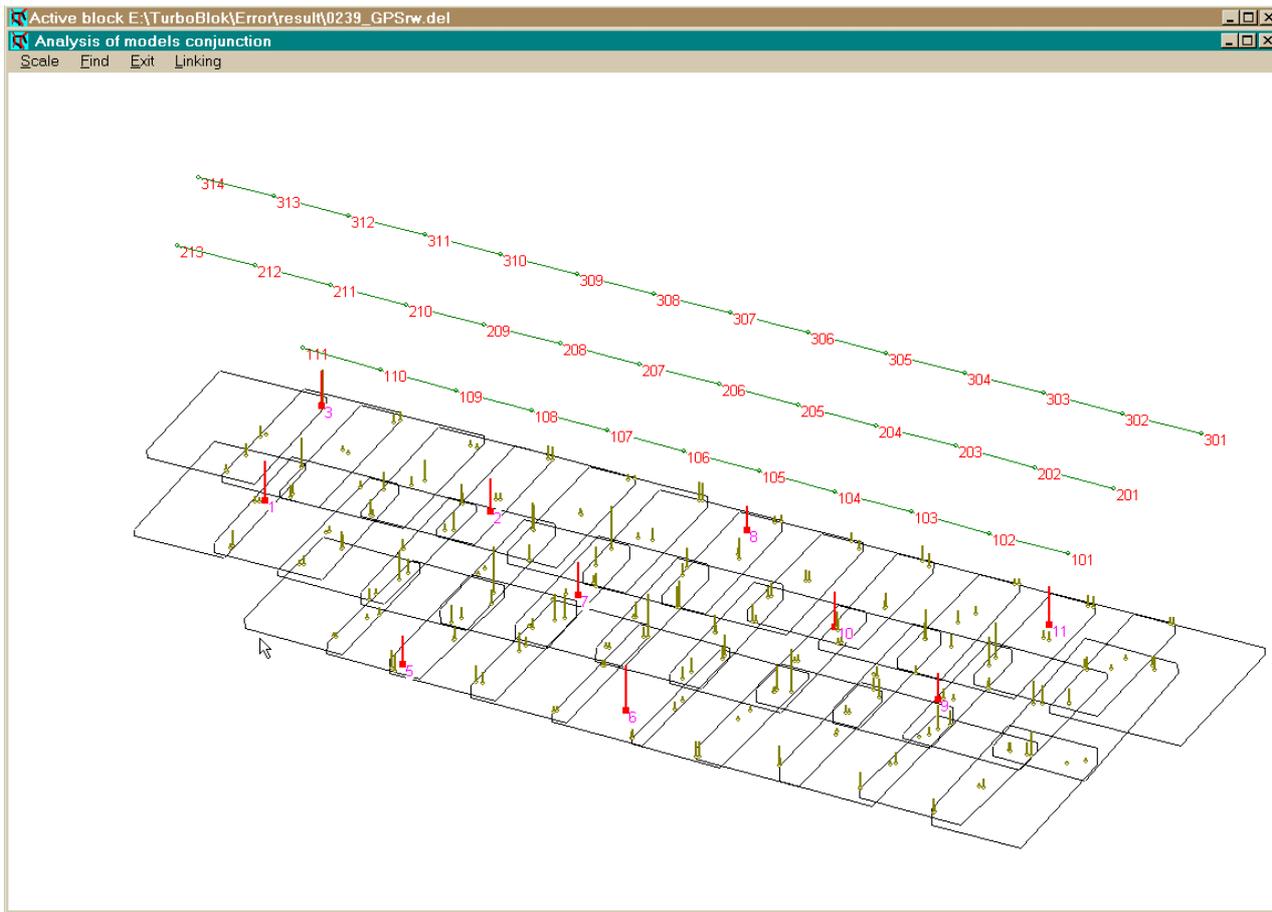
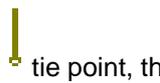
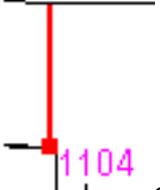


Fig. 2.5

The network scheme created in the window contains:

- black rectangles – the boundaries of the stereopairs on the terrain;
-  green circles conjoint with a line – photography bases with numbers of camera stations;
-  tie point, the vertical line means closing error in relative scale;
-  control point, the vertical line means closing error in relative scale; red color means horizontal-elevation control point, crimson color means horizontal control point, green color means elevation control point;
-  camera station which is the control point of the network.

The scheme of ground points and camera stations is represented in perspective projection. Choice of a point of view on the spatial location of network elements is made as follows. Keeping the left mouse button, you can move the cursor on a screen and choose the most suitable view of the scheme.

The menus of "Analysis" command

**2.1.3.2.1. Service/Analysis/Scale> command:**

- <Scale/Zoom In F4> – increases scale by 1.1
- <Scale/Zoom Out F3> – decreases scale by 1.1
- <Scale/1:1> – fits in the window

**2.1.3.2.2. <Service/Analysis/Find> command**

**<Find/Point>** – the cursor is being transforming into the arrow . Move the cursor to the point needed on the scheme and click the left mouse button. The closest tie point is found in the network, and the window is opened (Fig. 2.6). The bottom part of the window contains the data as follows:

- number of the closest tie point;
- numbers of the stereopairs on which it was measured;
- next three columns are deviations (in meters) of coordinates on each stereopair with regard to their adjusted values;
- next two columns are coordinates of the point on the left photo of corresponding stereopair, they are used for the identification of multiple measurements of the point on the same stereopair.

Double click the left mouse button on the number of a stereopair to show a source data of this pair from standard \*.kmp file at the top of the window. The cursor will be moved automatically to the position in front of the row, which contains the measurements of the current point.

Data are editable; changes will be saved in a source file or in another file.

The network scheme shows the maximum deviation of the current point. The additional window contains the scheme of location for measured points on the photos of stereopair. Double click the left mouse button to maximize the window.

**<Find/Frame>** – the cursor is being transformed into the arrow  and being moved to the area needed on the scheme. Keeping the left mouse button, build rectangle, within which you can select the points for analysis of coordinate deviations. Releasing the left mouse button, open the information window, the contents of which is described above. **Click the right mouse button to close the information window.**

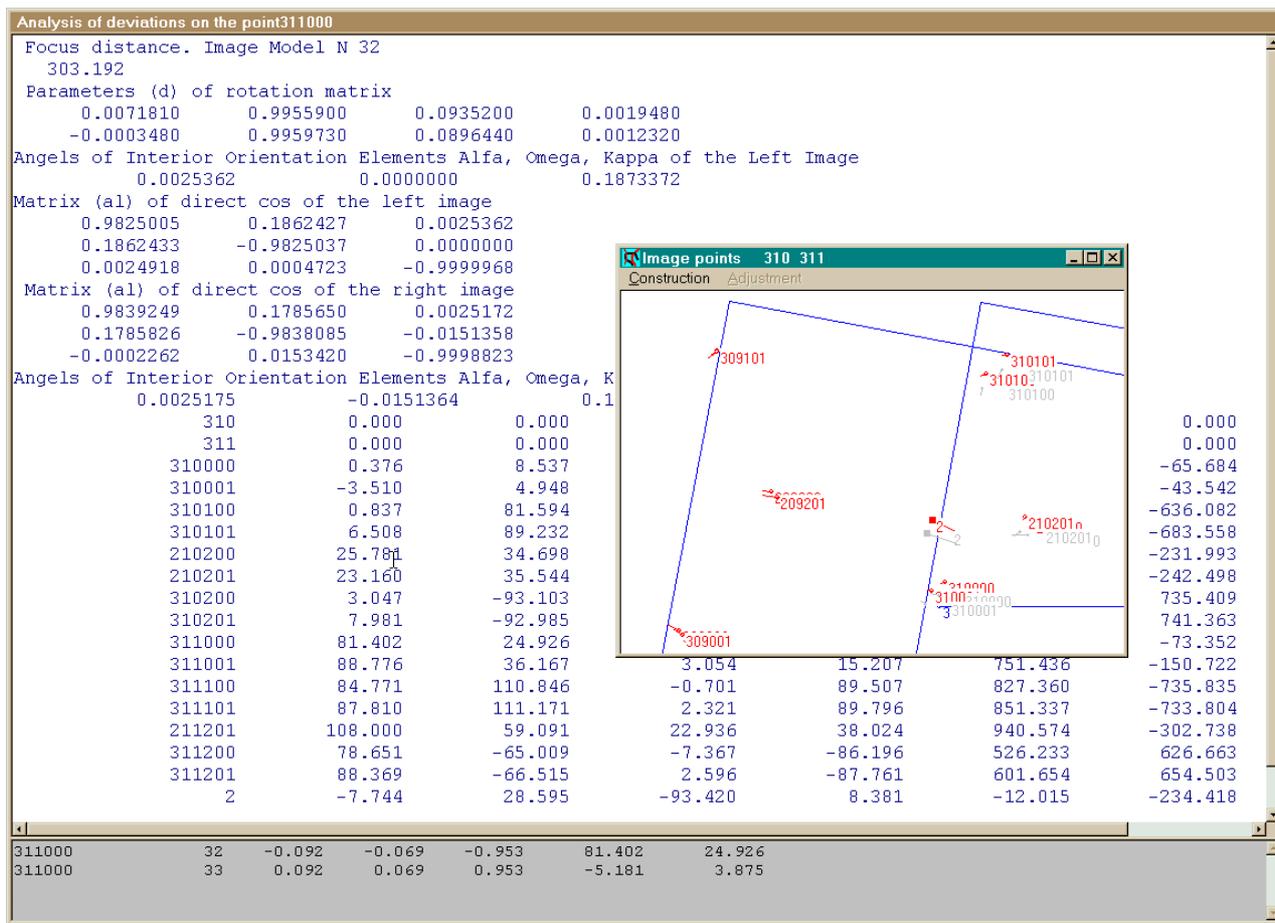


Fig. 2.6

The additional window contains the location of points on the photo of that stereopair, which data are shown in the main window (Fig. 2.7).

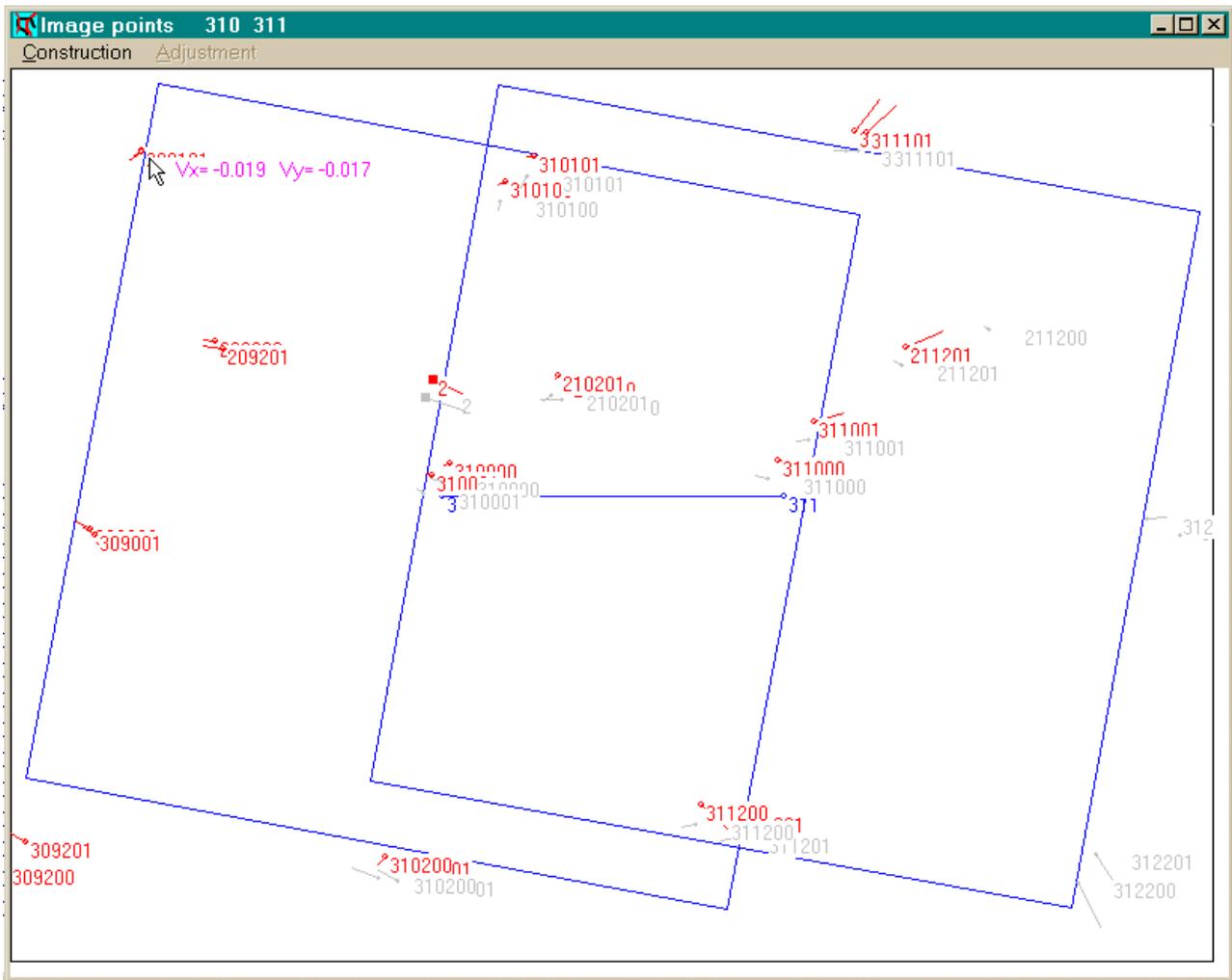


Fig. 2.7

You can open the additional window by double clicking on them. It contains the outlines of photos. Near each point you can see its number and line, the length of which corresponds to closing error of collinearity equation. If, keeping the button Shift, to move the cursor to the point, a screen will contain the numerical values of closing errors separately for each point (violet color).

The menu bar contains two commands: **<Construction>** and **<Adjustment>**. If **<Construction>** is enabled, it means that closing errors correspond to results of combination of the models into the block, i.e. after the construction of the block. If **<Adjustment>** is enabled, closing errors correspond to results of rigorous adjustment of the block. Availability of the commands changes by clicking the cursor.

If the state of the command after clicking is not changed, it means that rigorous adjustment is not executed and the command **<Create documents>** is not executed after completion of iterations.

#### 2.1.3.2.2. **<Service/Analysis/Exit> command**

**<Exit>** – closes the window of analysis of models' combination.

#### 2.1.3.2.3. **<Service/Analysis/Tie> command**

**<Tie>** – if the command is named "Tie", it means that the scheme contains coordinate deviations of the tie points and ground control points. After clicking on the command by the left button, the following items appear:

**<Control>** and **<Plan>**. It means that the scheme contains deviations of plane coordinates of the network control points. After clicking on the item **<Plan>** by the left button, the following items appear:

**<Control>** and **<Heights>** – the scheme contains height deviations of the network control points.

**<Navigation>** – this name appears after clicking on **<Control>** by the left mouse button only in case of construction of the block using navigation data. Repeated clicking returns to the state "Tie".

### 2.1.3.3. <Service/Import> command

Use this command to read a file with results of photos' measurement on stereoanagraph or stereocomparator and to transform them into standard internal file format with \*.kmp extension. In this case, you can come to an agreement with a customer concerning data formats for connection of the program with technology of photos' measurement in one or another enterprise/firm.

### 2.1.3.4. <Service/Export> command

This command calculates coordinates of image points on the photos, using adjusted values of geometric network elements, and creates a file with block source data **exportbl.kmp**. A file is created in the directory where the program is located. If to process the block from this file, then theoretically all corrections equal to zero. In practice, there are deviations from zero caused only by rounding mistakes in calculations; they not exceed  $1 \mu m$ .

### 2.1.3.5. <Service/Accuracy> command

The command opens the window for graphical analysis of accuracy of terrain points coordinates, obtained as a result of phototriangulation network adjustment. It allows you to visually evaluate the mistakes of ferial triangulation. The network scheme built in the window is analogous to the scheme described in section 2.1.3.2. <Service/Analysis> command. Select point or group of points on the network scheme to see the additional window (Fig. 2.8). This window contains in succession: the number of point and average square mistakes  $m_x$ ,  $m_y$ ,  $m_z$  of terrain point coordinates X, Y, Z. Average square mistakes of coordinates are calculated using the rigorous method of the least squares. Mistake of the unit of weight  $\mu$  is assigned as equal to value calculated using the results of the block adjustment.

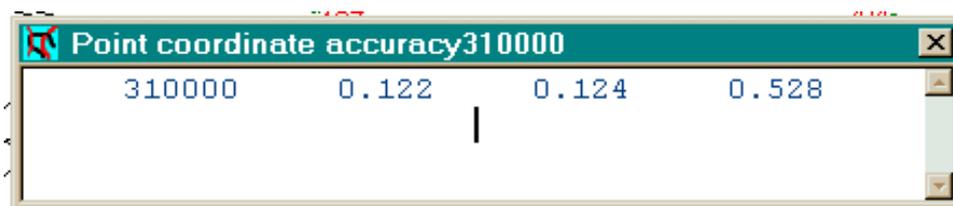


Fig. 2.8

Click the right mouse button to close the information window.

### 2.1.3.6. <Service/Prospect> command

Use this command to set the prospect center for better clearness of the network scheme. The first representation of the network scheme assumes that the prospect center is located on Z-axis in infinity, i.e. you obtain orthogonal terrain projection onto horizontal plane. There is a special window for the prospect center setting. In this window, the central circle contains direction and mutual location of the projections of geodetic coordinate axes onto picture plane. Keeping the left or right mouse button, move the cursor on the gray rectangle to change the prospect center setting.

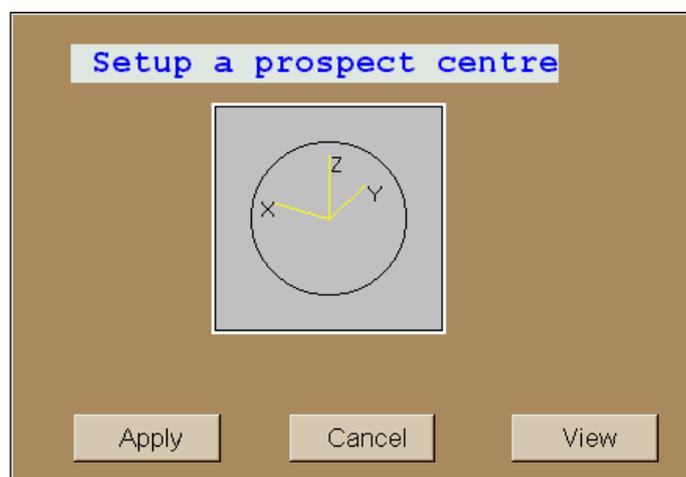


Fig. 2.9

Double click the left mouse button to close this window, the next double clicking will restore it. The obtained scheme of the block is 3D and has better clearness (Fig. 2.5).

**Attention!** It is possible to set the prospect center in the window of the network scheme directly. Use “Analysis” and “Accuracy” commands. Keeping the left mouse button, move the cursor on the scheme. To change size of the network scheme, move the cursor to the left or to the right, keeping the right mouse button.

Observing the changes in the view of the scheme, choose the direction needed and the distance of the cursor movement, and get the clear view of the network.

#### 2.1.4. <Calculation> menu

##### 2.1.4.1. <Calculation/Construction> command

This command is available after current block has been opened. The command combines the independent models into a unified block. Calculations are accompanied with the visualization of the processing in the opened window. This window shows the processed points in the network scheme dynamically. The iteration process with maximum correction in unknowns is shown in the status bar.

The iteration process takes less time if rough mistakes are absent in the measurements and in the construction of the phototriangulation network. After passing four cycles the program makes request “to continue the iteration process?”. If iterations take too much time, it is recommended to cancel them. Then, after analyzing the obtained results, make corrections to source data and repeat calculations from the beginning.

##### 2.1.4.2. <Calculation/Adjustment> command

This command is available after the block has been constructed. The command can be applied repeatedly for the opened block. The process of adjustment is visualized in the opened window, like during the block construction. After passing four iterations the program makes request “to continue the iteration process?”. In case of adjustment with autocalibration, i.e. with exclusion of systematic mistakes of photos, a necessity to take into account the systematic photo distortions is requested.

#### 2.1.5. <Options> menu

Use this menu to set the parameters and methods for measurements’ processing (Fig. 2.10). Settings are saved in case of closing the program or processing the next phototriangulation network.

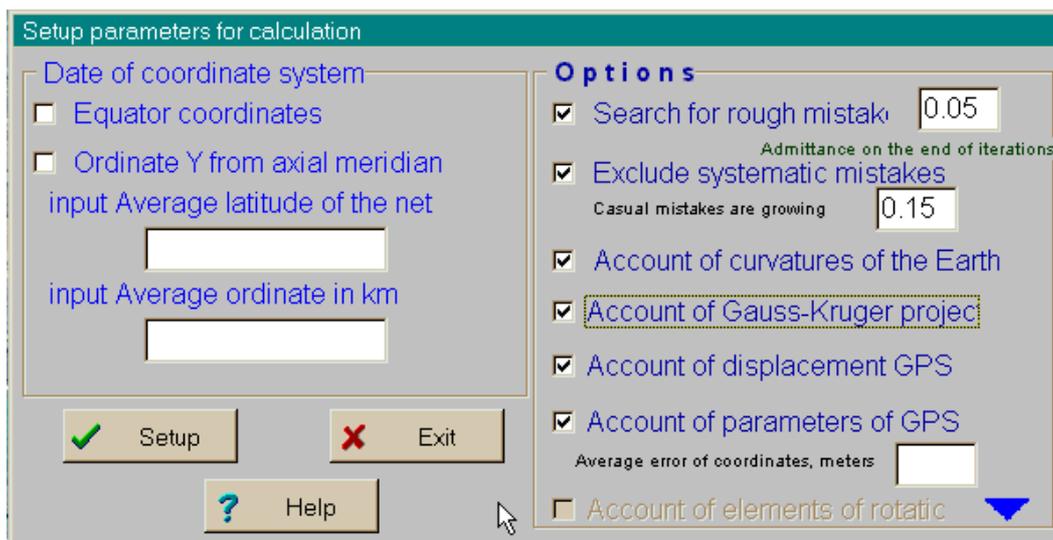


Fig. 2.10

Set the flag in the checkbox near the necessary option to enable this option. Enter the numerical values in the edit dialog boxes. The numerical values shown in the figure are recommended. These values are determined by practical experience of processing the measurements of real photos.

The menu is available only after opening the project of phototriangulation network. At this moment in the right bottom corner you see the triangular sign. Click on it to widen the form and see the view (Fig. 2.11):

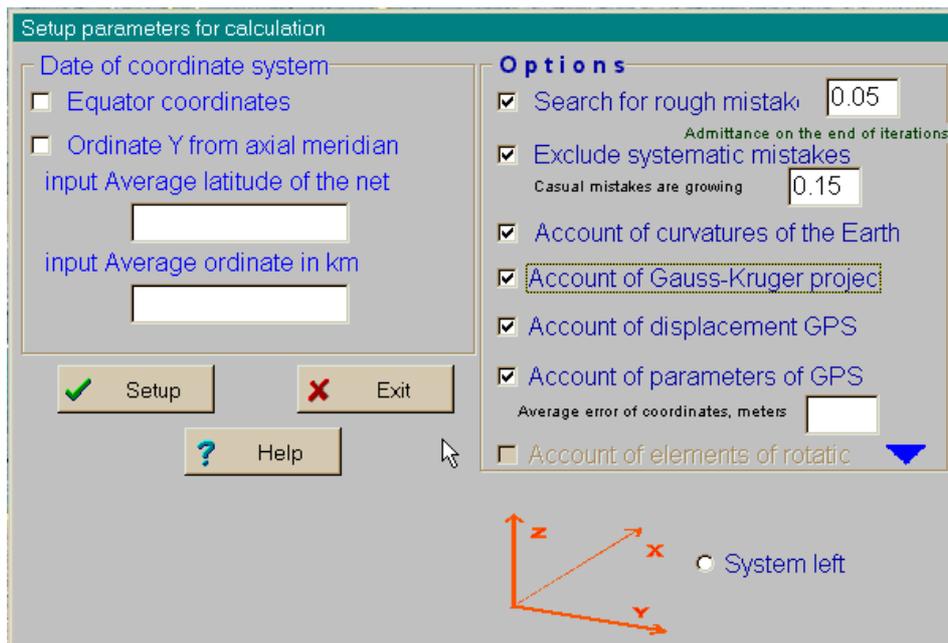


Fig. 2.11

In the additional part of the form, the scheme of coordinate system orientation is shown. Coordinates of control points of the network are set on this scheme. Before opening the network, the “system left” is set by default. Click to change it for right orientation. In further calculations, the set coordinate system for control points is used.

After construction of the network it is impossible to change the axes orientation, the triangular sign is invisible.

The options’ meaning and fixing correspond to the technology of construction of phototriangulation networks. For their simple understanding, the following explanations are given in order of location on the form.

**Date of coordinate system** – this group of options is available if the option **Account of Gauss-Kruger projection** is chosen; it is used for consideration of coordinate format in the system of Gauss-Kruger.

**Equator coordinates** – chose it if coordinates X are given in full and determined distance from Equator to the point.

**Ordinate Y from axial meridian** – chose it if the value of coordinate includes the number of zone and the displacement of coordinate origin to 500 km.

**Input average latitude of the net** – if the option **Equator coordinates** is not chosen, input the latitude of average point of the network in degrees.

**Input average ordinate in km** – if the option **Ordinate Y from axial meridian** is not chosen, input distance to the axial meridian of the zone in km.

**Search for rough mistakes** – if this option is chosen, the network construction/adjustment is made using the method of the least modules (by Laplace) for adjustment. The little window is opened, in which the tolerance for the completion of iterations is set. The tolerance is compared with maximum correction in unknowns in previous iteration (Fig. 2.12). The process is repeated until maximum correction is less than the tolerance. Decrease of the tolerance can considerably increase the number of iterations and consequently the duration of processing, but it does not considerably influence the efficiency of disclosure of rough mistakes.



Fig. 2.12

**Exclude systematic mistakes** – if this option is chosen, the adjustment is executed with estimation of the parameters of systematic mistakes by the method of self-calibration. According to theory, the degree of accumulation of casual mistakes of photo measurements in the calculated coordinates of terrain points increases. The edit dialog box is opened, in which the permissible average value of increasing in average square mistakes of the calculated coordinates is set (0.15 – average square mistakes of coordinates of terrain points on average can be increased in 15%).

**Account of displacement GPS** – if this option is chosen, the adjustment algorithm determines the vector of displacement of receiver's antenna concerning the center of camera objective. If geometric connections in the network are insufficient, only several projections of the vector are calculated; the negative influence of others is minimized.

**Account of parameters of GPS** – if this option is chosen, the adjustment algorithm determines the mutual orientation of coordinate systems of navigation data and ground control points. If geometric connections in the network are sufficient, seven parameters are determined. Else the optimal combination of them is selected automatically. The edit dialog box is opened, in which you can indicate average square mistake of coordinates' estimation in navigation measurements. This parameter will be used for estimation of ratio of weights for adjusted data. If not to fill in the edit dialog box, the algorithm determines the needed ratio, but the duration of processing slightly increases.

### 2.1.6. <Result> menu

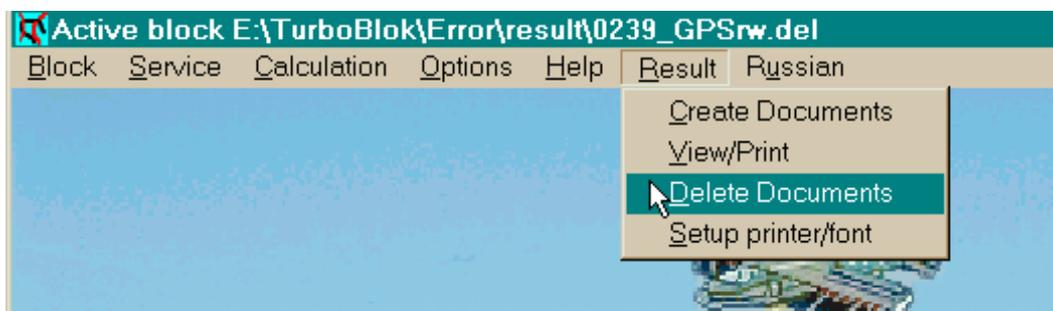


Fig. 2.13

#### 2.1.6.1. <Result/Create Documents> command

Using the processing results, this command forms the output text ASCII files. These files have the same names with the source data files, but different extensions.

The list of output files:

- <block name>.kmp source data file in standard format;
- <block name>#.kmp file is analogous with source file, which is created after block construction. Adjustment is executed by the method of the least squares, i.e. without searching for rough mistakes;
- <block name>\$.kmp file is analogous with source file, which is created after block construction. Adjustment is executed by the method of the least modules, i.e. with searching for rough mistakes;
- <block name>.knt catalogue of coordinates of control points and their deviations during block construction
- <block name>.doc protocol of block construction and adjustment
- <block name>.gau coordinates of points after combination of independent models
- <block name>.out deviations of coordinates of tie points on stereopairs calculated using the results of block construction
- <block name>#.001 catalogue of coordinates of ground control points
- <block name>#.002 catalogue of orientation elements of photos
- <block name>#.003 catalogue of coordinates of terrain points calculated using the results of rigorous adjustment of block
- <block name>#.004 catalogue of coordinates of photo points and corrections to them calculated using the results of rigorous adjustment
- <block name>#.005 catalogue of coordinates of terrain points in ascendant order of numbers of points
- <block name>#.006 setting elements of the exterior orientation of photos of stereopairs calculated using the results of rigorous adjustment
- <block name>#.knt catalogue of coordinates of control points and their deviations after block adjustment
- <block name>#.dat numbers and adjusted coordinates of terrain points
- <block name>.nav catalogue of recalculated coordinates of navigation data calculated using the results of block construction

`<block name>#.naw` catalogue of recalculated coordinates of navigation data calculated using the results of block adjustment  
`paramsys.dat` calculated values of parameters of systematic mistakes of photo measurements

A symbol \$ instead of # means that block construction and adjustment were executed using the method of the least modules.

Other files are temporary; they are deleted during closing a block.

#### 2.1.6.2. **<Result/View/Print> command**

Multi-paged interface is shown, in which you can descry the output text files or to print them.

#### 2.1.6.3. **<Result/Delete Documents> command**

This command deletes all output and temporary files except a source file **\*.kmp** and an analogous file, the name of which contains symbol # or \$.

#### 2.1.6.4. **<Result/Setup printer/font> command**

This command allows you to set printer and font type and size for printing the tables with results. Nevertheless, it is recommended to print the results using any full value text editor.

## 3. Program control in packet regime

Phototriangulation program **BlockMSG** can be initialized from another application. To do it, you can use the possibilities of command bar.

Command bar format:

`BlockMSG.exe <file name> [MAXITERATIONS=i] [SYSTEMA=0|1] [ADJUST] [CREATE] [STORE] [CLOSE] [EXIT] [MAXIMIZE]`

`<file name>` – file name including path. It includes information about a block in format of a source file with **.del** extension;

`MAXITERATIONS=i` – determines i – maximum number of iterations in calculations; by default the number of iterations in interactive working regime of the program equals to 5, in packet regime – 10. The parameter is determined if large number of iterations is waited. Such situation exists when data includes rough mistakes or the network has unsustainable geometric shape;

`SYSTEMA=0|1` – by default this parameter equals to 1, i.e. coordinate system of ground control points is “left”, as it is accepted in Ukraine and other countries of the CIS. Value 0 corresponds to “right” coordinate system;

`ADJUST` – sets the network adjustment, i.e. corresponds to **<Calculation/Adjustment>** command;

`CREATE` – sets the creation of documents of calculation results, i.e. corresponds to **<Calculation/Adjustment>** command;

`STORE` – saves the program sets and temporary results, that allows to come back to continue processing the network in interactive regime, i.e. corresponds to **<Block/Store>** command;

`CLOSE` – closes the block, deletes the temporary files and saves the output calculation results, i.e. corresponds to **<Block/Close>** command;

`EXIT` – unloads the program, but saves the settings and temporary files for the processed network, i.e. corresponds to **<Block/Exit>** command;

`MAXIMIZE` – opens the window of form during the program works in packet regime.

The only necessary parameter is <file name>, the order of others is arbitrary, and the separator between them is blank. If the unnecessary parameters are absent, the opening and construction of the network is executed, after that the program turns to interactive regime. If the parameter contains the grammar mistake, it is ignored. During the work of the program in packet regime the window of form is minimized, if the parameter MAXIMIZE is not set. Other options are set in interactive regime of program and are used in packet regime.

## 4. Phototriangulation using navigation measurements

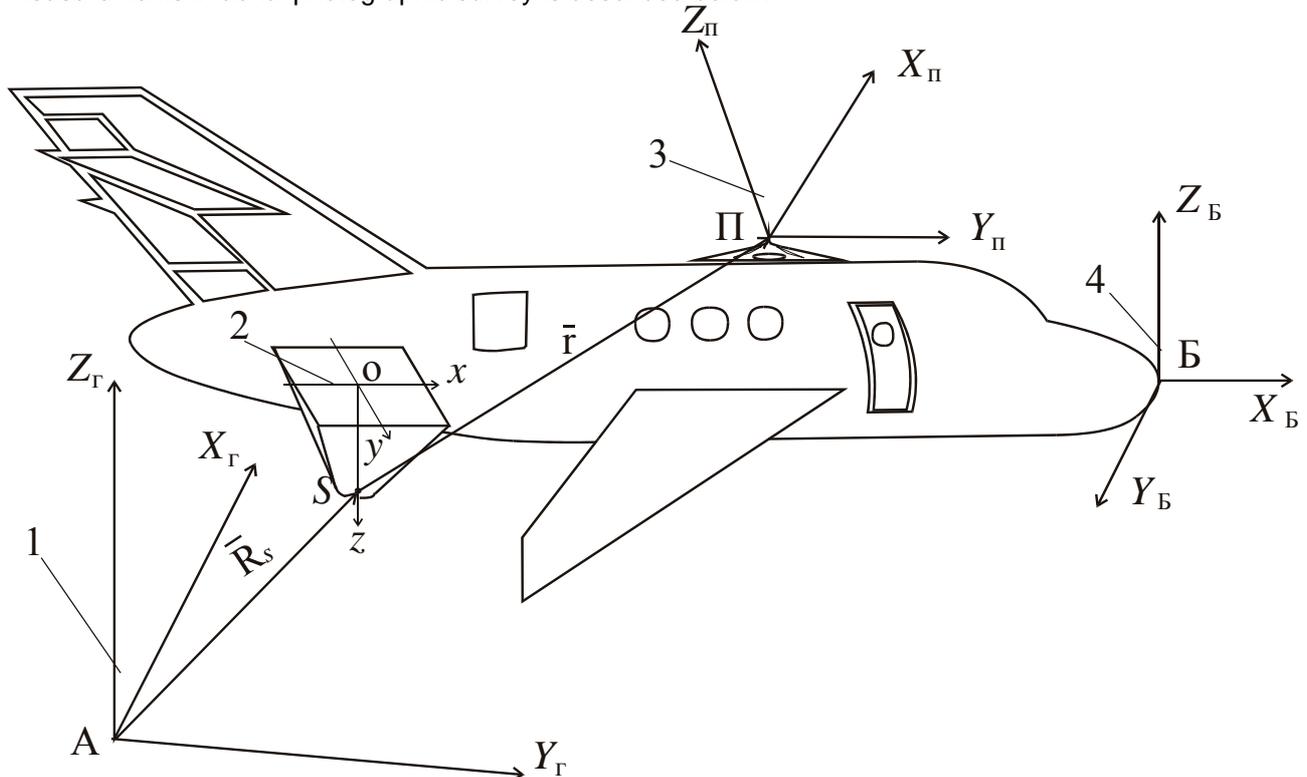
### 4.1. Conception of using navigation measurements

Navigation measurements in aerial photographic survey or in engineering photographic survey can be used in phototriangulation considering the following technological conceptions:

- navigation measurements are reduced to camera station of the corresponding photo and are used further as its hard linear and angular elements of exterior orientation;
- navigation measurements are directly included in construction and adjustment of phototriangulation network, when the reductions of navigation and photogrammetric measurements are considered on the base of geometric connections.

The first conception is realized in version 3 of the complex **BlockMSG** and it is traditional for the existing systems of analytical phototriangulation.

New version 4 (2003) of the complex **BlockMSG** realizes both conceptions. Geometric model of navigation measurements in aerial photographic survey is described below.



**Scheme of geometric elements of navigation measurements**

- 1 - coordinate system of the terrain (geodetic);    2 - coordinate system of camera;  
 3 - coordinate system of satellite navigation;    4 - system of measurements of angular elements of orientation.

**Fig. 4.1**

During the application of the first conception it is necessary to assume that before the construction of phototriangulation network, from the additional measurements or investigations the following items are known:

- a) vector  $\bar{r}$  in projections to axes of system 2 /**displacement of antenna of GPS receiver**/;
- b) mutual location of systems 1 and 3 /**parameters of GPS system**/;
- c) angular elements between systems 2 and 4 /**elements of rotation**/.

It is hard to execute these requirements in usual practice; sometimes it is practically impossible. In the second conception, all these elements or any group of them are calculated from the combined adjustment of photogrammetric and navigation measurements.

If in the phototriangulation network it is impossible to calculate all parameters theoretically, the processing algorithm automatically selects their optimal quantity, others are marked as not calculated and it is shown **what part of their values influences the adjustment results**. It allows you to project the technology of navigation measurements more flexibly, to use the approximate values of geometric parameters and to reduce the residual values by combined adjustment.

Even in the most precise satellite measurements' processing, coordinates of camera stations obviously are not agreed with geodetic coordinates of ground control points of phototriangulation block, therefore estimation of the parameters from group b) is always justified. The parameters of GPS system are calculated using the assumption that dependence between coordinate systems 1 and 3 is described by orthogonal transformation with scale not equaled to 1.

#### 4.2. Options of construction and adjustment of phototriangulation block

Options are set in the window "Options" which has some additions.

If the option **Account of parameters of GPS** is chosen, the window is opened for entering the value of  $m_H$  – average casual mistake of satellite measurements of coordinates in meters. This calculation parameter is necessary for considering the ratio of weights of photogrammetric and navigation measurements. If you not enter the value, the program sets the optimal ratio of weights automatically.

#### 4.3. Adjustment results considering navigation measurements

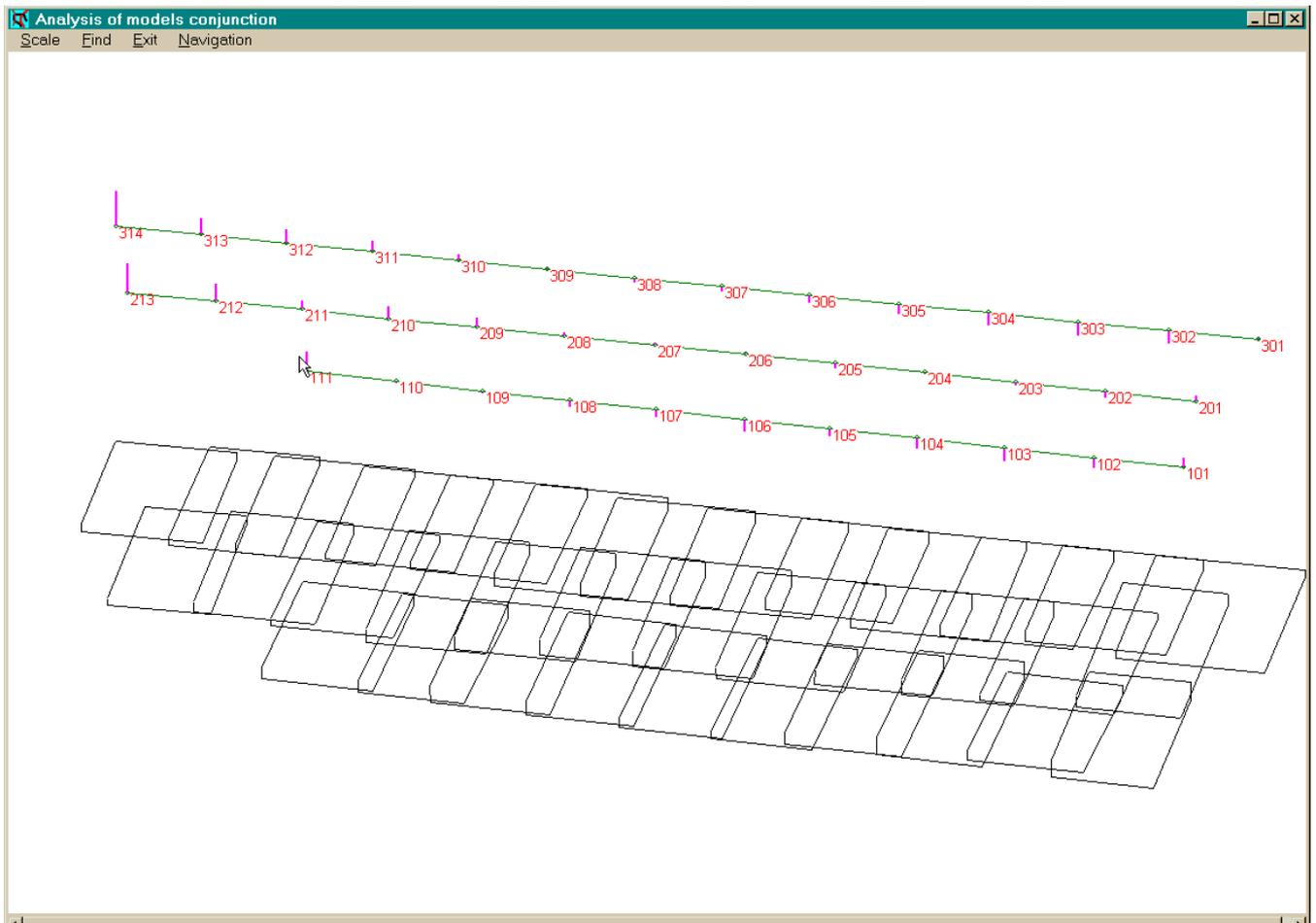
In case of combined adjustment with navigation measurements, the following output files are added:

- [<block name>0.naw](#) catalogue of navigation coordinates recalculated into geodetic system and reduced to camera stations, and their deviations from coordinates of camera stations obtained **from the construction of phototriangulation network**;

- [<block name>#.naw](#) catalogue of navigation coordinates recalculated into geodetic system and reduced to camera stations, and their deviations from coordinates of camera stations obtained **from the combined adjustment of phototriangulation network**.

Graphical view of deviations of navigation data can be seen during the execution of **<Service/Analysis>** command and setting **<Navigation>** instead of **<Tie>** in the menu bar. For switching, click the left mouse button on the menu name (Fig. 4.1). The names are changed cyclically: **<Tie>**, **<Control>**, **<Navigation>**.

The values of coordinate deviation on Z-axis are represented by color vertical line.



**Fig. 4.2**

If only the construction of a block is executed, the deviations after combination of models are represented. After the combined adjustment of measurements, the deviations from adjusted navigation measurements are represented; they are considerably less, as a rule.

A file of calculations' protocol includes the results of consideration of navigation data. If some parameter is marked as calculated, the residual influence of its true value equals to 0.

The table includes the results of adjustment of real phototriangulation network.

Geometric connections of this network do not allow us to calculate reliably  $r_x$  – projection of vector  $r$  of displacement of receiver's antenna. Therefore it is marked as unknown, and it is shown that distortions in coordinates of camera stations will be only 0.03 of its value, i.e. 0.03  $m$  if the displacement of antenna is 1  $m$ . Of course, in this case it is enough to measure the vertical displacement of antenna on the carrier to within accuracy of one meter; other projections are determined from the combined adjustment. In the angular elements of exterior orientation of photos, the residual part of influence is slightly higher, but its absolute value is insignificant, i.e. the combined adjustment uses the information of navigation measurements considerably more efficiently.

The values of other parameters are sizable and if not to consider them, the network can be seriously deformed.

**Table 4.1. Results of combined adjustment of photogrammetric and navigation measurements**

Name of parameter	Calculation	Value of parameter	Part of residual influence in elements of photos	
			In coordinates of centers	In angles of slope
Displacement of antenna:				
along, m	calculated	6.884	0.000	0.000
across, m	calculated	5.306	0.000	0.000
plumb, m	unknown		0.030	0.245
Parameters of coordinate system of navigation:				
X origin, m	calculated	-3.727	0.000	0.000
Y origin, m	calculated	3.427	0.000	0.000
Z origin, m	calculated	-42.782	0.000	0.000
scale	calculated	1.000011	0.000	0.000
slope, radians	calculated	0.000095	0.000	0.000
bank, radians	calculated	-0.000342	0.000	0.000
turn, radians	calculated	6.282969	0.000	0.000
			0.000	0.000

Accuracy increasing at the expense of use of navigation data:

- in coordinates of camera stations 3.06 times
- in angles of slope of photos 3.02 times

Average square values of corrections to photocoordinates

- in X-axis in mm 0.006
- in Y-axis in mm 0.004

Average square values of corrections to navigation measurements

- in X-axis in mm 0.088
- in Y-axis in mm 0.079
- in Z-axis in mm 0.346

Mistake of the unit of weight in mm 0.007

#### 4.4. Advantages of combined adjustment of navigation and photogrammetric measurements

In new version 4 of the program **BlockMSG** you have a possibility with the help of different combinations of options to choose one of more than 300 models of mistakes of measured values. Choose those, which optimally reflects the peculiarities of your project.

The combined adjustment allows:

- find and localize rough mistakes in navigation measurements;
- make self-calibration of not only the camera, but of the whole survey complex without special measurements and investigations;
- increase accuracy and reliability of ferial triangulation;
- provide flexibility and reliability of project creation and realization.

## 5. Source data formats

Source data for the program **BlockMSG** can be prepared in the following basic formats:

- <Delta> – format of digital photogrammetric complex (Digitals-Delta)
- <PAT-B> – format of wide-spread analytical photogrammetric devices;
- <Standard> – standard internal format of the program **BlockMSG**.

After opening a block, source data are transformed into standard internal format, which is proceed.

### 5.1. Description of <Delta> data format

The format is used for interactive working regime as well as for packet regime, when it starts automatically directly from digital photogrammetric complex "Digitals-Delta".

A source file must have text format ASCII. Data unit is the measurements of one stereopair, in which coordinates of points on photos are reduced to the principal point. All possible corrections of a separate

photo, e.g. for orientation on fiducial marks, deformation of base, distortion, etc., must be considered during the direct measurements. The order of proceeding the stereopairs is arbitrary, independently on the type of a photo (aerial, ground, space), complexity of a block and location of control points. Generalized data structure of a block is as follows:

```

<Name of phototriangulation block>
<Coordinates of control points>
$$
<Navigation measurements>
@@
<Stereopair №1>
##
<Stereopair №2>
##
.
.
.
<Stereopair №n>
##

```

**<Name of phototriangulation block>**

- includes the row of symbols for block identification, can include also the control parameters for calculations in packet regime (see 3);

**<Coordinates of control points> section**

- data about control points are located in rows, each row has the structure as follows:

**<name of point> <X> <Y> <Z> <Code>**

**<name of point>** – name of point, contains up to 20 any symbols;

**<X> <Y> <Z>** – coordinates of point, separated by blanks, have a decimal point “.”;

**<Code>** – code of control point;

‘1’ – only Z coordinate is given;

‘2’ – X and Y coordinates are given;

‘3’ – X, Y and Z coordinates are given;

‘5’ – camera station has known Z coordinate;

‘6’ – camera station has known X and Y coordinates;

‘7’ – camera station has known X, Y and Z coordinates;

‘Xk’ – control point ‘X’ (register and language of “k” have not influence);

**<Navigation measurements> section**

- **this section is not necessary**, it includes the rows of data on navigation measuring the coordinates of camera stations, each row has the structure as follows:

**<name of photo> <X> <Y> <Z> <Code>**

**<name of photo>** – name of camera station, contains up to 20 any symbols;

**<X> <Y> <Z>** – coordinates of camera station, separated by blanks, have a decimal point “.”;

**<Code>** – code of camera station;

‘5’ – camera station has known Z coordinate;

‘6’ – camera station has known X and Y coordinates;

‘7’ – camera station has known X, Y and Z coordinates;

**<Stereopair №n> section**

- in the first row

**<name of left photo> <name of right photo> <focal distance of photos>**

then the rows contain coordinates of points on photos of stereopair

**<name of point> <x – on left photo> <y – on left photo> <x’ – on right photo> <y’ – on right photo>**

Example of data form in phototriangulation block

```

Phototriangulation block <Name of project>
6650уцк 430084.35 51689.15 114.33 3
4530 115.17 1

```



The next row of a section contains:

**<name of point> <x coordinate of point on photo> <y coordinate of point on photo>**

**<name of point>** – a word without blanks, contains up to 20 symbols;

**<x coordinate of point on photo> <y coordinate of point on photo>** – coordinates of point representation on a photo, reduced to the principal point of a photo, in  $\mu m$ .

Tracks can follow each other in arbitrary order, but the photos in a track must be located in succession, two adjoining photos should compose a stereopair.

If the photos in a track are located in succession, in which the photography was executed, then inclusion of navigation data into adjustment provides the highest accuracy of the results.

Example of data of photos' measurements

	213	303192	2	
212000		-88187		-9371
212001		-83854		-7199
212100		-90764		91866
212101		-91150		87075
212200		-112823		-82623
212201		-113312		-80236
213000		-5908		-4155
213001		3442		78
213100		-326		102604
213101		281		102944
213200		-49784		-85483
213201		-45828		-96958
1		-92160		-13358
		-99		
	212	303192	2	
211000		-85015		34331
211001		-87350		29931
211100		-85428		110367
211101		-81381		111169
111200		-113444		65412
111201		-113806		62493
211200		-90827		-62895
211201		-113048		-68170
212000		176		-4194
212001		4555		-2103
212100		-286		98453
212101		-691		93513
212200		-23322		-76199
212201		-23812		-73866
213000		84520		-739
213001		94606		3237
213100		92782		107647
213101		93413		107981
213200		38809		-80051
213201		42899		-91313
1		-3844		-8095
		-99		
	211	303192	2	
210000		-85477		8995
210001		-85247		7797
210100		-85049		110544
210101		-88761		99970
110200		-105802		72875
110201		-110192		58133
210200		-110350		-100329
210201		-112557		-98740
211000		2252		5373
211001		-59		902
211100		-48		79755

211101	3886	80715
111200	-26410	34658
111201	-26738	31769
211200	-305	-92931
211201	-23143	-99350
212000	88912	-29037
212001	93201	-26731
212100	83916	72183
212101	83795	67358
212200	70753	-103560
212201	70128	-101172
	-99	

File with coordinates of ground control points

Data in the file are located in rows:

**<name of ground control point> <X coordinate> <Y coordinate> <Z coordinate>**

**<name of ground control point>** – a word without blanks, contains up to 20 symbols;

**<X coordinate> <Y coordinate> <Z coordinate>** – coordinates of ground control point, in meters, the separator is a blank.

It is assumed that all ground control points have coordinates. If a ground control point has not the complete set of coordinates, necessary correction can be made after opening the block, the **<Service/Editor>** command can be executed (see 2.1.3.1). The correction is made in a file in **<Standard>** format with **\*.kmp** extension. This file is created during the block opening.

Example of data with geodetic coordinates of ground control points

6	6701551.830	607734.869	492.23
7	6705235.957	612081.631	227.65
8	6703055.429	616246.537	422.65
9	6695680.253	612107.076	188.68
10	6699340.315	613786.846	185.76
11	6694898.796	616026.545	377.21
12u	6691967.185	607368.369	629.80
13	6693339.865	614194.578	298.12

File with navigation measurements of coordinates of camera stations

Data in the file are located in rows:

**<name of camera station> <X coordinate> <Y coordinate> <Z coordinate>**

**<name of camera station>** – a word without blanks, contains up to 20 symbols;

**<X coordinate> <Y coordinate> <Z coordinate>** – coordinates of camera station, in meters, the separator is a blank.

This file is similar to the file with coordinates of ground control points.

### 5.3. Description of <Standard> data format

This data format is the internal format of the program **BlockMSG**. It is used for suitable adaptation of different technologies of photos' measurements.

Data are placed in one text ASCII file. This file consists of sections, which are the same as in **<Delta>** format.

Data file has the structure as follows:

**<Name of phototriangulation block>**

**<Coordinates of control points>**

**\$\$**

**<Navigation measurements>**

**@@**

**<Stereopair №1>**

**##**

**<Stereopair №2>**

**##**

.  
.  
.  
**<Stereopair Nnn>**  
**##**

First two sections have a format, described in 5.1. Further data are divided into sections, corresponding to separate stereopairs. The separator is a code '##'.  
Order of data location and explanations are represented in the example.

**Example of data of one stereopair in <Standard> format**

```
Focus distance. Image Model N 1
303.192
Parameters (d) of rotation matrix
0.0434520    0.9975990    -0.0528360    -0.0107830
0.0001350    0.9995040    -0.0266360    -0.0168240
Angels of Interior Orientation Elements Omega Phi , Kappa of the Left Image
-0.0169225    0.0000126    6.1766129
Matrix (al) of direct cos of the left image
0.9941841    -0.1063558    -0.0169217
-0.1063708    -0.9943265    0.0000126
-0.0168271    0.0017874    -0.9998568
Matrix (al) of direct cos of the right image
0.9980150    -0.0532503    -0.0336237
-0.0559900    -0.9946666    -0.0866228
-0.0288317    0.0883335    -0.9956736
Angels of Interior Orientation Elements Omega, Phi , Kappa of the Right Image
-0.0337570    -0.0867315    6.2269544
202 0.000 0.000 0.000 0.000 0.000 0.000 0.000
201 0.000 0.000 0.000 0.000 700.000 0.000 0.000
201000 76.349 56.137 -10.498 37.192 515.986 -509.075 -2423.179
201001 80.019 54.014 -6.769 35.327 547.067 -495.585 -2424.727
201100 88.463 -78.767 5.453 -97.326 703.256 531.434 -2350.307
201101 82.630 -69.577 -0.635 -88.084 653.268 467.375 -2357.612
. . . . .
. . . . .
202200 17.654 81.633 -68.980 58.604 29.642 -658.406 -2404.683
202201 20.530 79.989 -66.123 57.189 53.710 -648.028 -2405.674
##
```

The contents of first 17 rows are described in the text.  
Eighteenth row contains the name of a left photo, next four figures are always equal to zero, and last three figures are spatial orthogonal coordinates of center of a left photo of the model.  
Nineteenth row contains the same data for a right photo.  
Starting from twentieth row, data for each point of the model are located in the order as follows:

**<name of point> < $x_L$ ><  $y_L$ ><  $x_R$ ><  $y_R$ ><  $X$ ><  $Y$ ><  $Z$ >**,

where

$x_L, y_L$  and  $x_R, y_R$  – coordinates of point representations on a left and right photos respectively,  
 $X, Y, Z$  – spatial orthogonal coordinates of point of the model, in meters.

Each model can have its own system of spatial orthogonal coordinates. They will be combined into one model at the stage of block construction.

During dialog data processing, especially during the analysis of data quality and search for rough mistakes, it is recommended to make corrections to a file with \*.kmp extension, in which search for needed row with data is made automatically.

## 6. Model of source data mistakes

You can control the calculations by setting different options and their combinations. It allows you to construct and adjust a phototriangulation network considering the peculiarities of measurement mistakes and geometric ratios between measured values. Total number of ratios of options is quite high, more than 300, therefore only the most typical, having practical meaning, are described.

## 6.2 Calibration of elements of interior orientation of camera

The elements of interior orientation include focal distance, coordinates of principal point, and photogrammetric distortion of the image. The values of first two items are often known with sufficient accuracy. Distortion, even after correction of coordinates on photo according to data of camera laboratory calibration, is not completely excluded. In the program **BlockMSG**, its influence can be highly decreased by choosing the option **Exclude systematic mistakes** during adjustment (see 2.1.5).

In this case, the parameters of systematic mistakes of photos are calculated and saved in file `paramsys.dat`. The parameters are the coefficients of polynomial, which approximates the systematic distortions of images. Corrections to measured coordinates of image points are calculated by the formulas:

$$\delta_x = a_1 10^{-1} + a_2 x 10^{-2} + a_3 y 10^{-2} + a_4 x^2 10^{-4} + a_5 y^2 10^{-4} + a_6 xy 10^{-4} + a_7 x^2 y 10^{-6} + a_8 xy^2 10^{-6} + a_9 x^3 10^{-6} + a_{10} y^3 10^{-6};$$

$$\delta_y = a_{11} 10^{-1} + a_{12} x 10^{-2} + a_{13} y 10^{-2} + a_{14} x^2 10^{-4} + a_{15} y^2 10^{-4} + a_{16} xy 10^{-4} + a_{17} x^2 y 10^{-6} + a_{18} xy^2 10^{-6} + a_{19} x^3 10^{-6} + a_{20} y^3 10^{-6},$$

where

$\delta_x$ ,  $\delta_y$  – corrections to coordinates of image point  $x$  and  $y$  respectively, in *mm*;

$x$ ,  $y$  – coordinates of image point, in *mm*;

$a_1, a_2, \dots, a_{20}$  – parameters of systematic mistakes of images, their values are saved in output file `paramsys.dat`.

Multipliers  $10^{-k}$  are used for convenience of calculations.

Parameters

$a_1, a_{11}$  reflect the corrections to coordinates of principal point of photo;

$a_2, a_3, a_{12}, a_{13}$  reflect the corrections to focal distance and uniform deformation of photo.

Other coefficients consider nonlinear distortions of image (distortion, deformation, etc.). They can be calculated using the materials of survey of standardized polygon with considerable density of ground control points and accuracy of source data. In this case they can be used for consideration of camera calibration.

Approximate correction  $\delta f$  to focal distance of photos can be calculated by the formula:

$$\delta f = f \frac{\sqrt{(1 + a_2 10^{-2})^2 + 10^{-2} a_{12}^2} + \sqrt{(1 + a_{13} 10^{-2})^2 + 10^{-2} a_3^2}}{2},$$

where  $f$  – focal distance of photos, used during block adjustment.

Modern non-topographic digital cameras have considerable value of objective distortion. This value is such that, if to use not corrected coordinates of images, the uncertainty of combined orientation of photos can arise.

The program **BlockMSG** can be used for processing the measurements executed during the photogrammetric calibration of cameras.

### 6.2. Consideration of reduction between optical center of objective and camera station

Geometric scheme of measurements, described for navigation measurements (see 4), can be used also for other cases, e.g. for non-topographic application of phototriangulation.

It is practically impossible to precisely estimate and measure the position of optical center of objective. Nevertheless, in precise ground photogrammetric survey it is preferable for increasing the accuracy of results to use the coordinates of centers of projections, measured by geodetic method. Application of conception of navigation measurements, accepted in **BlockMSG**, allows you to solve this task.

In this case, instead of measuring the center of objective, it is enough to measure the coordinates of some point on camera frame. This point is immovable relatively the objective during survey process. Then during block adjustment it is possible to consider these measurements as navigation measurements, and to adjust them taking into account existing reduction. If before adjustment to enter into navigation measurements the

approximate corrections to reduction, then final results are less distorted by those composite parts of reduction, which in current network are impossible to calculate.