Digital photogrammetric systems and technologies of the photogrammetry chair of MIIGAiK

Prof. Dr. A. **Tchibounitchev**
Dean of Photogrammetry Faculty
Moscow State University of Geodesy and Cartography

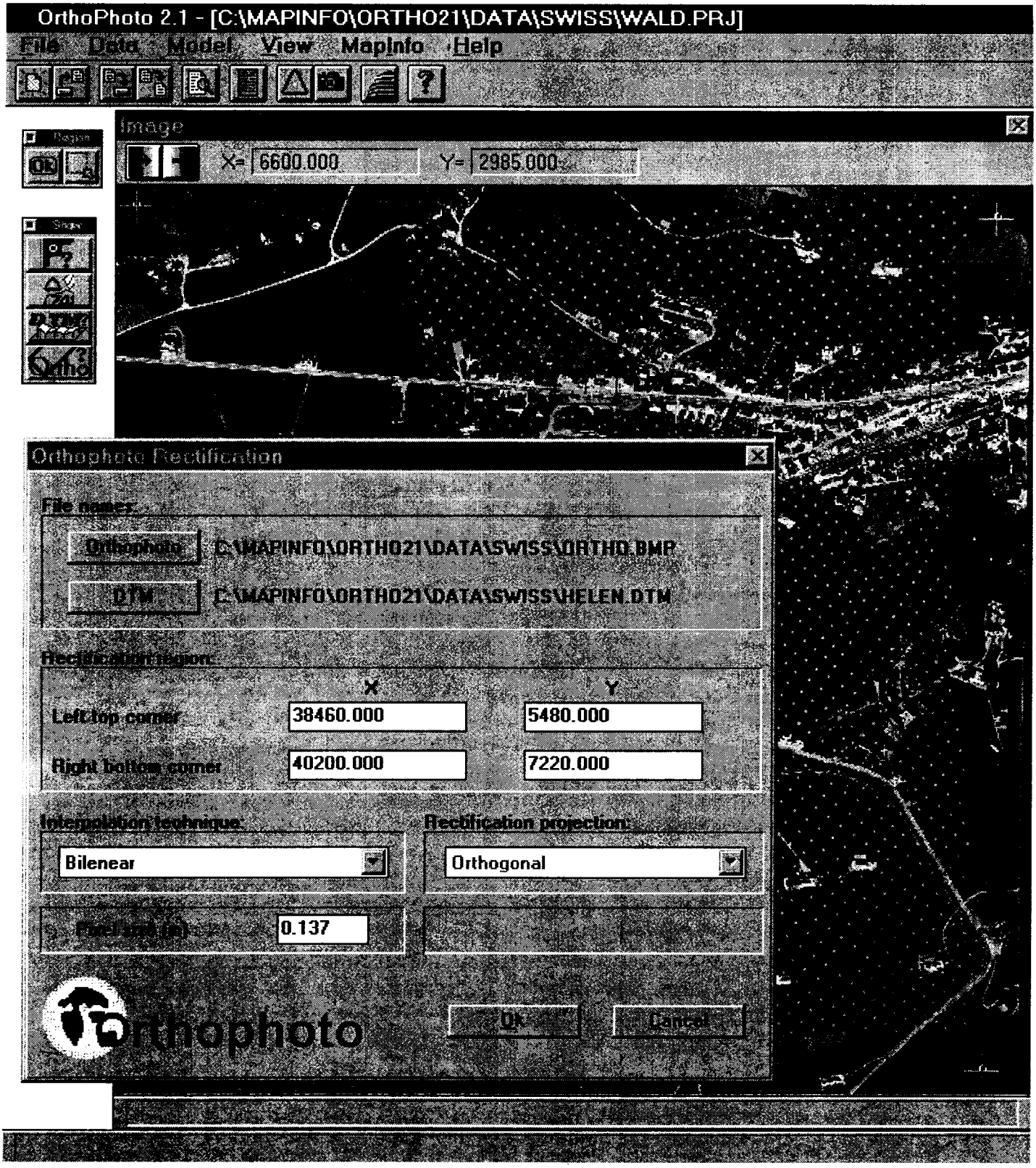
Photogrammetry chair of Moscow State University of Geodesy and Cartography (MIIGAiK) is intensively developing automatic photogrammetric digital cartographic and cadastrial technologies, solutions for noncartographic problems using aerial and space materials and terrestrial photoimages.

Over the period of time from 1991 to 1994, research and development of photogrammetric workstations based on all types of stereocomparators and analogue and analytical stereoplotters have been executed on the photogrammetry chair of MIIGAiK. The mechanical and electronic devices developed for all these photogrammetric workstations provide compatibility between photogrammetric equipment and a personal computer with corresponding software installed aimed to solve all photogrammetric tasks.

In 1994-1996 the digital photogrammetric workstation «Orthophoto» has been developed. This workstation is intended for obtaining the digital images in a map projection from single aerial image and digital terrain model (if present). Moreover, large orthoimages can be created as a mosaic of combination of several, rectified digital images. The software covers the following processes: inner orientation, determination of exterior orientation elements of the image from control points, rectification and mosaic production. Besides, by loading this orthophoto or mosaic image as a raster layer of a map in one of GIS or CAD systems you can gather topographic data or revise a map. The special table for automatic registration of orthophoto or mosaic in GIS «MapInfo» can be created.

Workstation has been written on Borland C ++ language. It is working in Microsoft Windows environment. The software has no restrictions on the initial image sizes. During the software development special attention was paid to convenience and simplicity of operators work. There were implemented automatic positioning of the measuring mark in the appropriate regions of fiducial marks and ground points, zooming in and out of the image to obtain subpixel accuracy of measurements, different measuring mark forms, radiometric image correction, flexible definition of the orthophoto area, radiometric matching of adjacent images during mosaic process and etc. Automatic accuracy estimation for all processes of orthophoto and mosaic creation is taking place. For input and storing of the initial information the appropriate editors and cameras database were supplied. The protocol of all processes done, is creating in two kinds: as the graphics on the image, and as the textual information in the log file.

Workstation already used for creation of topographic and cadastrial maps from aerial images and architectural plan using terrestrial images in some industrial organisations of Russia and others countries as well.



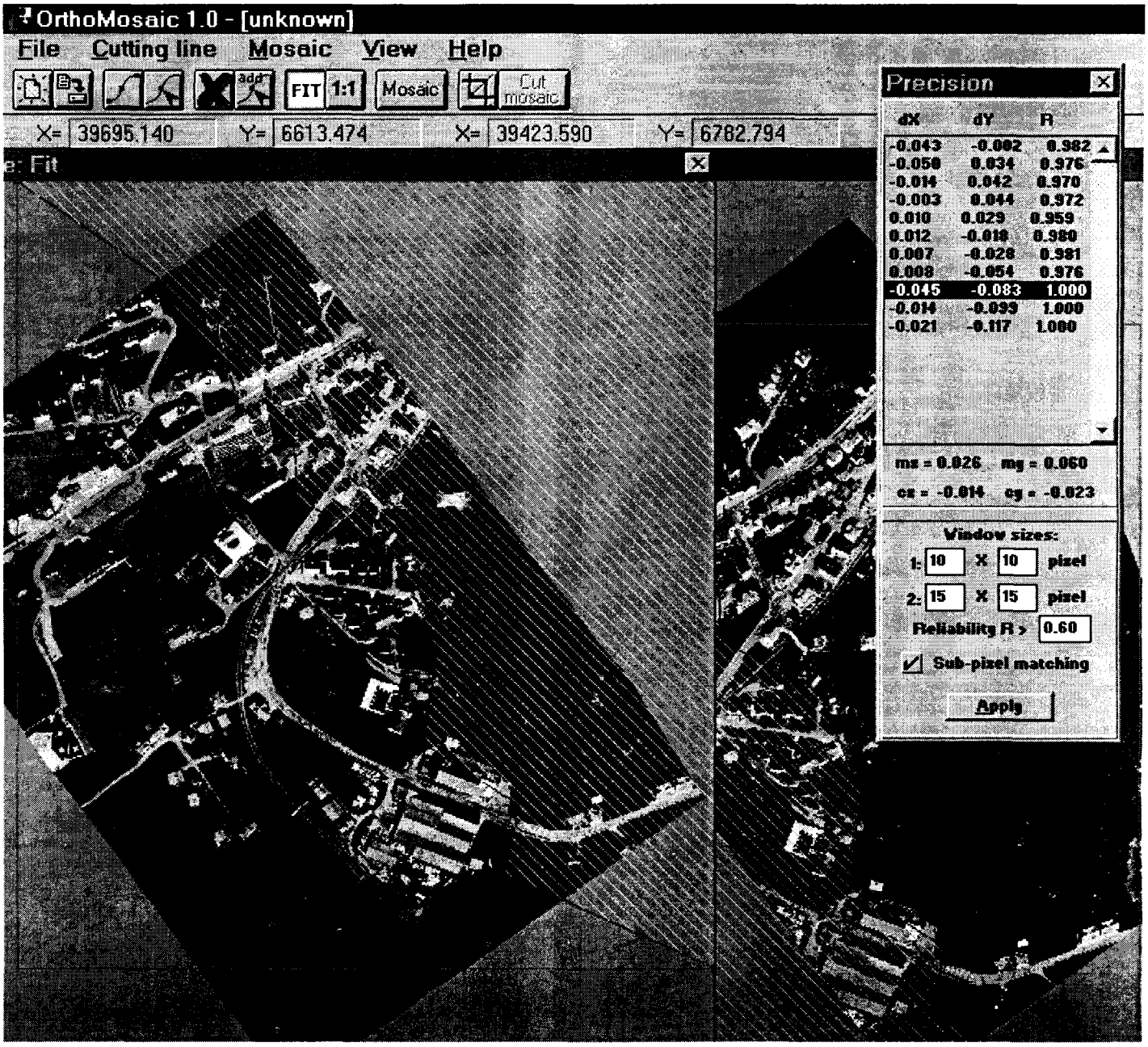

OrthoMosaic 1.0 - [unknown]
File
Cutting line
Mosaic
View
Help
FIT
1:1
Mosaic
Cut mosaic
X= 39695.140
Y= 6613.474
X= 39423.590
Y= 6782.794
Fit
Precision
dX dY R
-0.043 -0.002 0.982
-0.058 0.034 0.976
-0.014 0.042 0.970
-0.003 0.044 0.972
0.010 0.029 0.959
0.012 -0.019 0.980
0.007 -0.028 0.981
0.008 -0.054 0.976
-0.045 -0.083 1.000
-0.014 -0.099 1.000
-0.021 -0.117 1.000
mx = 0.026 my = 0.060
cx = -0.014 cy = -0.023
Window sizes:
1: 10 X 10 pixel
2: 15 X 15 pixel
Reliability R > 0.60
Sub-pixel matching
Apply

Fig.2

Our chair is intensively working with company "Racurs" - the developer of Digital Photogrammetric Workstation "**Photomod**" helping to solve technological and scientific problems. This software implements the following processes:

- Aerial triangulation
- Automatic DTM extraction
- Orthoimage generation
- On-screen 3D-digitizing in stereo mode
- Orthomonoplotting
- Digital maps creation and output

Each process implemented a separate module of the "Photomod" software. Figure 3 shows the whole step-by-step technology and relationships between modules of the software.

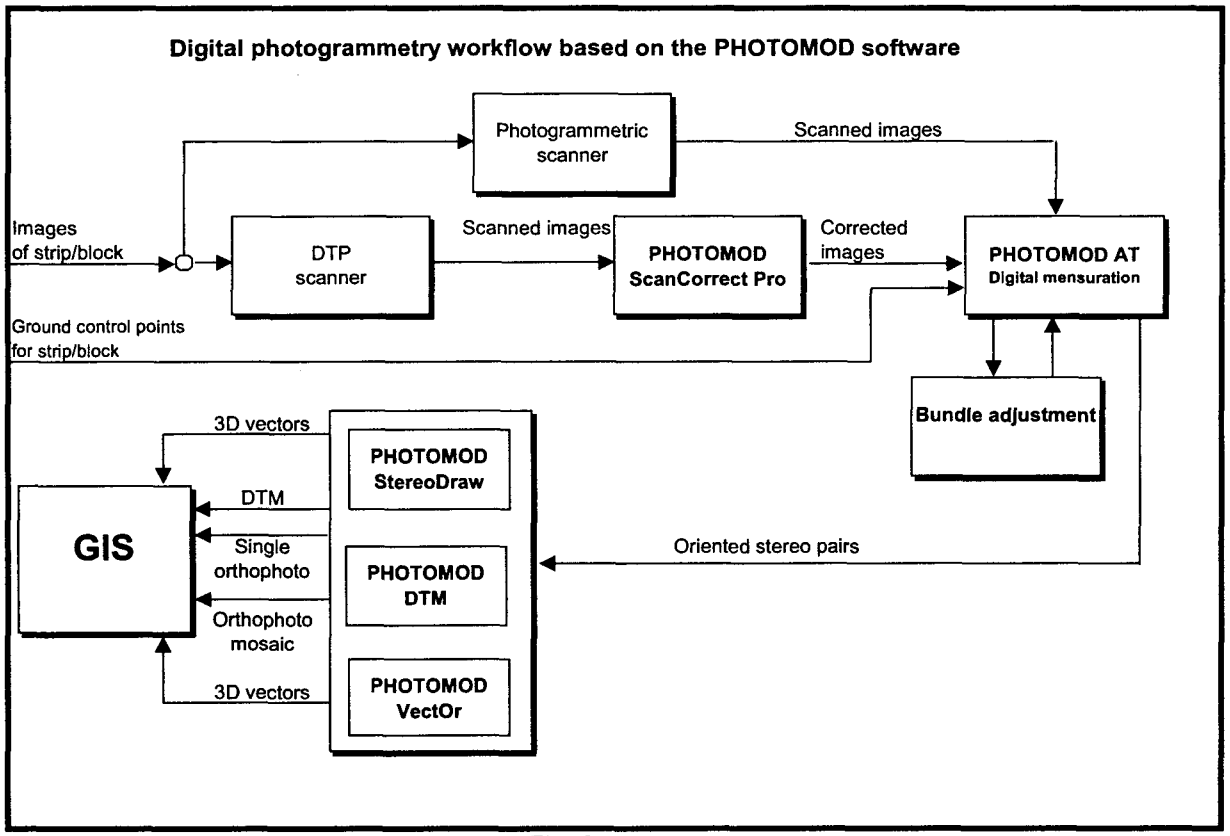


Fig. 3

PHOTOMOD ScanCorrect program is designed for the geometric calibration of desktop scanners. The program allows you to use inexpensive scanners in precise digital photogrammetry applications by means of the special image calibration procedure. Scanned images are geometrically corrected when processed by ScanCorrect module to remove the distortion and produce virtually error-free images.

PHOTOMOD AT performs a full set of digital phototriangulation computations for the block of images. The source data set for this module includes scanned images, interior orientation parameters and ground control points coordinates. Input data is processed by PHOTOMOD AT as follows: creating the project, interior orientation of

images, input of ground control points coordinates, interactive or automatic tie points measurements, relative orientation, bundle adjustment. Exterior orientation parameters for all images of the block are calculated as a result of bundle adjustment procedure. Block images resample to epipolar geometry can be transferred as a set of stereo pairs to PHOTOMOD StereoDraw, PHOTOMOD DTM and PHOTOMOD VectOr modules for further processing. PHOTOMOD AT provides a complete information about errors at every production step.

PHOTOMOD SP is designed for a single stereo pair processing. The processing includes following steps: data base (project) creation, input of interior orientation parameters and control points coordinates, interior/relative/external orientation of the stereo pair, transformation to the epipolar geometry, 3D measurements. PHOTOMOD SP (versus PHOTOMOD AT) is more suitable in cases of terrestrial survey and images, produced by non-metric cameras.

PHOTOMOD DTM performs automatic DTM extraction for the selected portion of epipolar image as well as for the entire image. PHOTOMOD DTM supports several algorithms for the DTM extraction and visualisation (as TIN, colour-coded or hill-shaded surface). You can edit DTM (TIN) elements either as single ones or as selected groups, compute contour lines in the automatic mode and include to DTM previously created or imported vector objects as break lines. Source image can be orthorectified based on DTM and transferred to PHOTOMOD VectOr for on-screen digitising. Export to popular vector formats is available.

PHOTOMOD StereoDraw is a module for on-screen 3D digitizing. You can create, edit and make measurements of 3D vector objects both in mono and stereo viewing modes. PHOTOMOD StereoDraw provides a set of useful features such as automatic terrain following, fixing Z-coordinate of the cursor, snapping to 2D and 3D vector elements, plotting line segments at the right angle, copying and moving vector objects and many others. Some topology related operations are available as well as attribute database tables creation and editing. Import/export from/to number of popular data formats is supported and can be extended by DLLs, written by user.

PHOTOMOD VectOr - powerful vector-based GIS, used to create, edit and print out digital maps. PHOTOMOD VectOr uses orthoimages or DTMs, created in PHOTOMOD DTM as underlaying objects for on-screen monoplotting.

MIIGAiK continues to improve technologies of topographic and cadastrial plans creation. These technologies are based on the use of the Russian digital photogrammetric systems for phototriangulation adjustment, digital orthophotoplans and maps creation using stereo pairs of aerial images. The last technology shown on figure 4 was developed with the hard work of Dr. Lee Jun Hva.

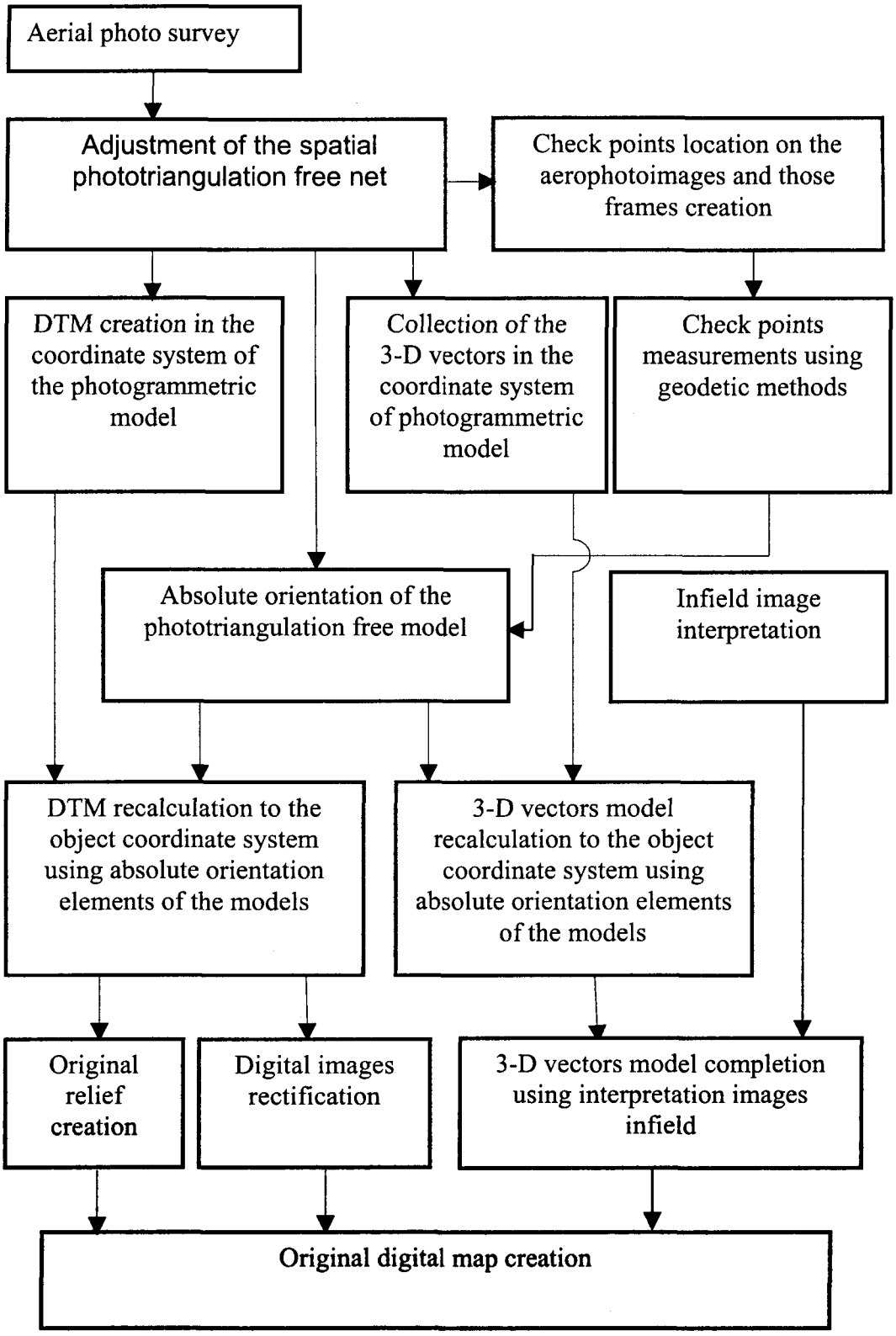


Fig.4

The aerophototopographical method of the map creation is fast compares to terrestrial topographic survey, but the time that takes to produce the final product is

quite big because it is usual to begin the photogrammetric work after the ground points determination and interpretation in field.
However, modern digital photogrammetric workstations allow doing the most part of the photogrammetric processes before finishing ground points determination and interpretation in field. For that purposes digital photogrammetric workstation should provide the construction and adjustment free phototriangulation at the given scale and angular orientation. During the net construction the photogrammetric relations between tie points in strip and between strips should be strictly controlled. After that the project of Check points location on the aerophotoimages and those frames is creating based on points measurements in the free net. Before the finishing of the fieldworks, on the area that covers the stereo pairs in the free net coordinate system the digital terrain model is creating and digital vector models of contours.
After the ground points determination and interpretation the absolute orientation is computing. So, the elements of the absolute orientation of each model are computing. After that, using the calculated elements of the absolute orientation of models, the recalculation of the DTM and 3-D vector model point coordinates should be done. The models, described above are uniting in the one terrain and 3-D vector model. The resulting DTM is using for creation of the original relief drawn by contour lines and digital photoplan if needed. For the digital map production it is necessary to add the results of the field interpretation to the digital vector map made using indoor interpretation materials. It is possible to use stereo vectorization for that purposes as well as vectorization of the photoplans in GIS and CAD software.
The technology described distributes the work of the groups of surveyors working indoor and in field equally as well as decreases the overall time of the topographic and cadastrial maps creation and therefore decreases the price of the whole work.

MIIGAiK done some experimental and industrial work to create topographical and cadastral maps at the scale of 1:2000, 1:1000 и 1:500. It confirms the efficiency of the described technology. All the work had been done using the "Photomod" digital photogrammetric system.

The photogrammetry chair is researching the ability to use the photogrammetry to solve non-topographical problems (architecture, machine building etc.) using photogrammetric cameras as well as non-metric cameras. For the calibration of non-metric digital cameras there was made the special software (Fig. 5) that allows to determine the elements of the interior orientation of the camera (focal length and the coordinates of the principal point) and the distortion of the lens. Calibration coefficients are calculating using measurements of the point's coordinates of the 3-D test object images. The chair of photogrammetry made the test object as a set of the marked points (Fig.6). Coordinates (XYZ) of these points were measured with accuracy of 0.1 mm using geodetic method. The mathematical bases of the calibration software are well known colinearity equations. The leans distortion is calculated using the following formula:

$$\mathbf{D_R} = \mathbf{A_1} \cdot \mathbf{R} \cdot \left(\mathbf{R}^2 - \mathbf{R}_0^2\right) + \mathbf{A_2} \cdot \mathbf{R} \cdot \left(\mathbf{R}^4 - \mathbf{R}_0^4\right)$$

Figure 7 shows the example of the digital camera calibration results...

Following the research work using several digital cameras, the relative accuracy of the object points coordinates determined by images that was obtained by these calibrated cameras is between 1/1000-1/5000. The whole process was made using "Photomod" software.

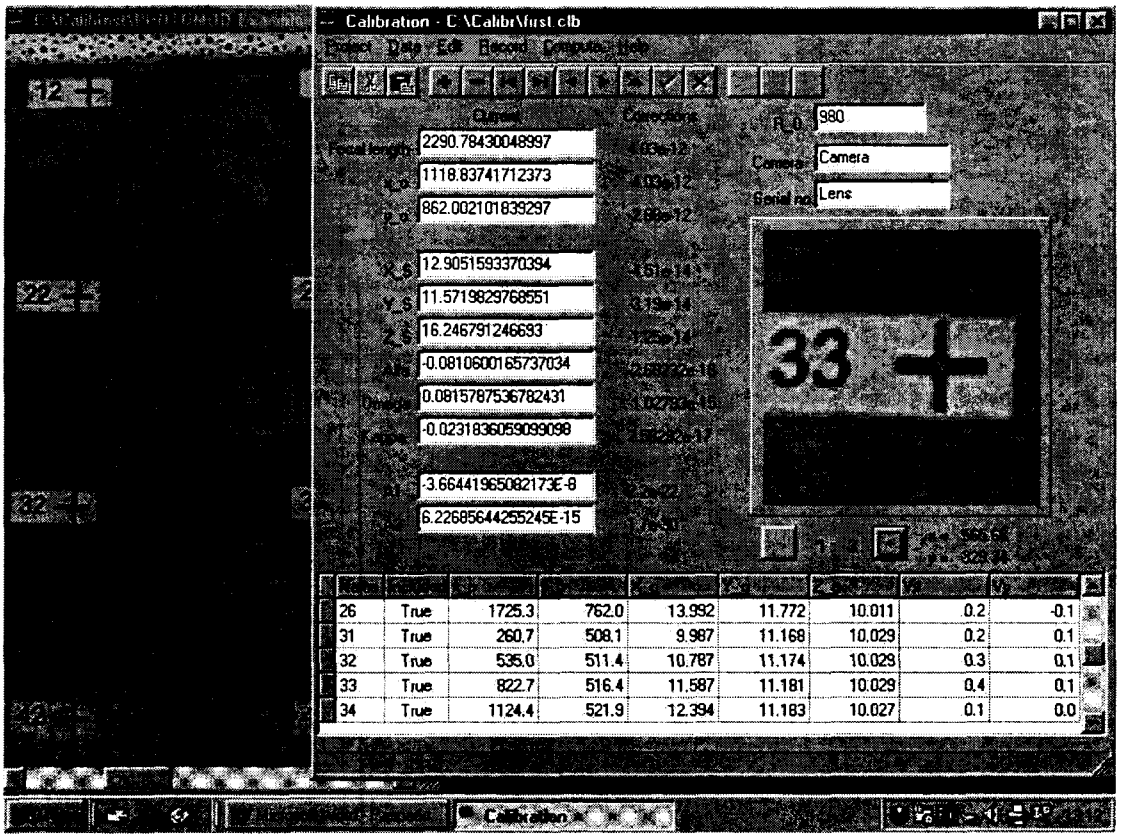

Calibration - C:\Calibr\first.clb
2290.78430048997
1118.83741712373
862.002101839297
12.9051593370394
11.5719829768551
16.246791246693
-0.0810600165737034
0.0815787536782431
-0.0231836059099098
-3.66441965082173E-8
6.22685644255245E-15
980
Camera
Lens
33
26 True 1725.3 762.0 13.992 11.772 10.011 0.2 -0.1
31 True 260.7 508.1 9.987 11.168 10.029 0.2 0.1
32 True 535.0 511.4 10.787 11.174 10.028 0.3 0.1
33 True 822.7 516.4 11.587 11.181 10.029 0.4 0.1
34 True 1124.4 521.9 12.394 11.183 10.027 0.1 0.0

Fig. 5

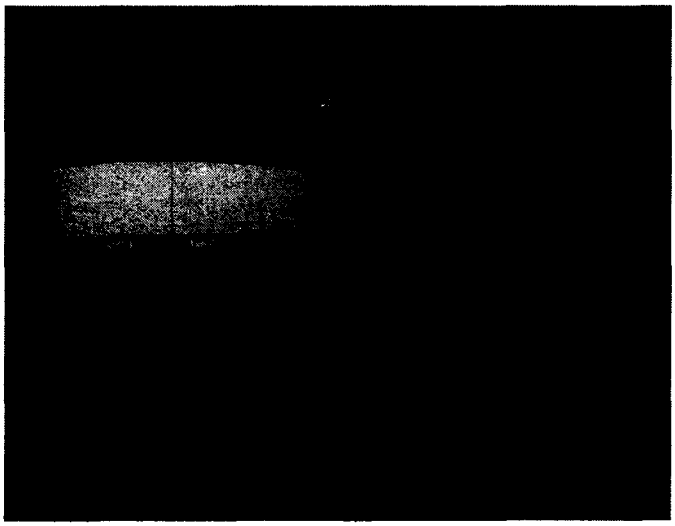
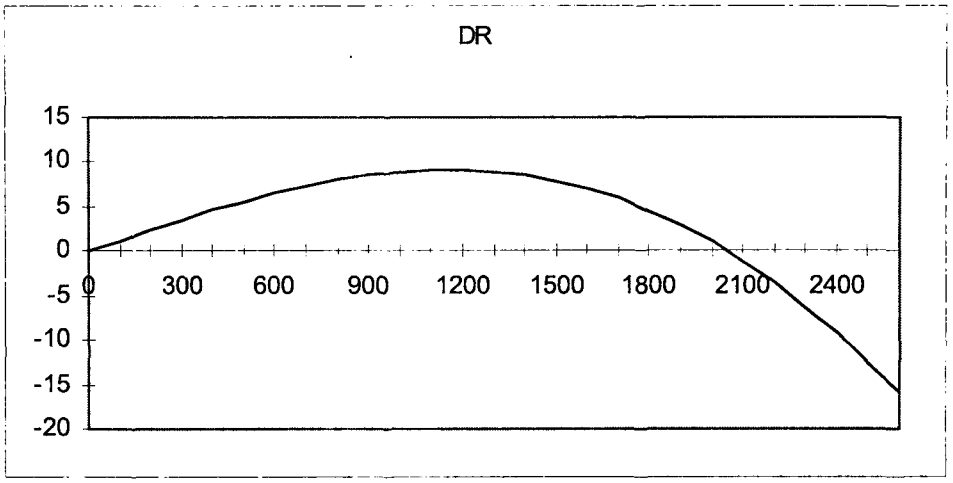
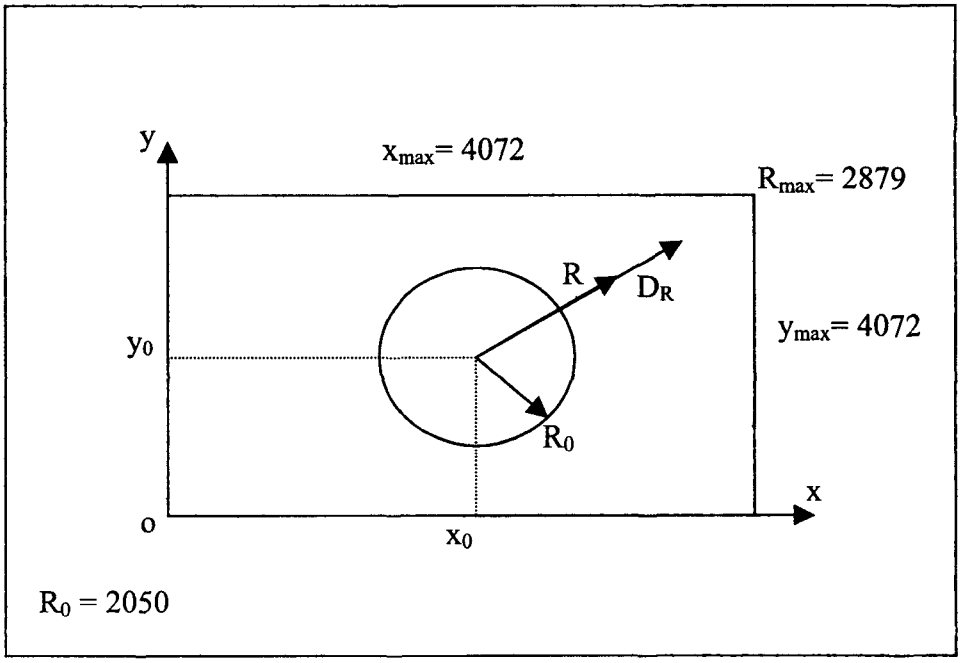


Fig.6

Certificate of digital camera calibration

R	DR
0	0,0
100	1,2
200	2,4
300	3,5
400	4,6
500	5,6
600	6,5
700	7,3
800	8,0
900	8,5
1000	8,9
1100	9,1
1200	9,1
1300	8,9
1400	8,5
1500	7,9
1600	7,0
1700	5,9
1800	4,6
1900	2,9
2000	1,0
2100	-1,1
2200	-3,5
2300	-6,2
2400	-9,2
2500	-12,5
2600	-16,0
2700	-19,7
2800	-23,7
2900	-28,0





$$D_R = A_1 \cdot R \cdot \left(R^2 - R_0^2\right) + A_2 \cdot R \cdot (R^4 - R_0^4)$$

f= 5594,0	Sigma= 2,3
x_0 = 2098,0	Sigma= 2,2
y_0 = 1985,1	Sigma= 2,4
A1= -3,13E-09	Sigma= 1,11E-10
A2= 6,62E-17	Sigma= 1,46E-17

Camera: MAMIYA RZ67 № TC 1422
Lens: MAMIYA SEKOR 50 № 32788
Digital photographic part: KODAK PRO BACK № DCSPB00150

Fig.7

At the present time we do the research work and at the same time are developing software for camera calibration using 2-D test object, that can be created much simpler than 3-D objects.