A PC - BASED SOLUTION FOR COMPUTER AIDED PHOTOGRAMMETRIC MAPPING ON ANALOG STEREOPLOTTERS

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ABSTRACT:

The development of the computer aided photogrammetric restitution in Yugoslavia during last decade has been conditioned by the following facts: procurement of the analytical instruments was impossible; analog stereoplotters still in good operating condition are dominant; utilization of the PC technology is extensive.

In such circumstances decision has been made at the Laboratory for Photogrammetry at Faculty of Civil Engineering in Belgrade to rely on the original, self-styled development of computer aided restitution based on instruments with mechanical construction and PC technology. The review of that development, the acquired experiences and the basic characteristics of the developed software are presented in the paper. All implemented solutions are completely in compliance with the modern software development, which means an open software that increasingly independent from the hardware.

Special attention is paid to the significance of the original development concerning GIS/LIS development in Yugoslavia and education of personnel acquainted with digital technology.

1. INTRODUCTION

Appearance of IBM PC compatible computers in the last decade enabled revolutionary progress in development of computer aided mapping on analog photogrammetric instruments. That progress was encouraged by technical development of PC computers and by constant tendency to decrease prices of PC components. In the middle 80-ies photogrammetric practice in Yugoslavia had great interest in application of analytical photogrammetric methods, first of all in block aerotriangulation, followed by interest in numerical photogrammetric restitution, and finally in completely digital photogrammetric mapping. However, at that time, such needs could be satisfied only by procurement of new analytical instruments.

Due to the economic difficulties, possibilities for significant renovation of the existing equipment with analytical instruments was simply out of question. Occasional procurements, that took place, did not significantly change situation in photogrammetric practice where analog instruments were dominant. Many of analog instruments were still in extremely good condition, so some compromised solutions were required. These solutions had to consider adaptation of the available instruments and possibly engagement of the existing photogrammetric operators in computer aided mapping.

2. CHRONOLOGICAL DEVELOPMENT OF COMPUTER AIDED PHOTOGRAMMETRIC MAPPING

The first steps in the field of computer aided photogrammetric mapping were made in 1987, when under the leadership of the Laboratory for Photogrammetry, Faculty of Civil Engineering in Belgrade, the original software and hardware system, named PPC system, for support of numerical photogrammetric measurement on analog instruments was developed. The main PPC system components at the time included:

- 8 bit PC XT encoder interface board (PPC board),
- IBM PC XT computer with peripherals,
- software for computer aided orientation and numerical photogrammetric measurement called PPCSoft.

Two years latter, in 1989, the system was extended with a new software package which enabled interactive computer support to measurement of independent models for block aerotriangulation. The package was also compatible with already developed PC software for block aerotriangulation adjustment using independent models. During the same year, the system was improved with 16-bit PC AT encoder interface board.

In 1991, prototype of the software for digital photogrammetric mapping was developed at the Laboratory for Photogrammetry, Faculty of Civil Engineering

in Belgrade. This software was relying on already developed software for support to model orientation (PPCSoft) and the software for support to block aerotriangulation (BINEM-IFM). However, this software required a much wider conceptional view, so it was designed as a software for complete support to digital geodetic map. The software was named MapSoft and one of the first developed modules was the module for digital photogrammetric mapping. In April 1992, the MapSoft started to be tested within survey of the town of Kragujevac.

Presently, in the region of the former SFR of Yugoslavia, 18 photogrammetric instruments, mostly made by WILD (WILD A7, A8 and A10) are equipped with PPC systems and PC compatible computers ranging from PC XT to PC 486. Eleven of these instruments are equipped with PC 486 computers and have complete software support to digital photogrammetric mapping.

Developed photogrammetric software can be linked to any device for 3D data acquisition on analog stereoplotters.

3. IMPORTANCE OF ORIGINAL DEVELOPMENT

After eight years of experience, the determination to start development of the original solution for computer aided mapping has proved to be right, because even now the situation in photogrammetric practice in Yugoslavia is not significantly changed in favour of analytical instruments. After eight years, the productivity and technical condition of the available photogrammetric equipment remained practically unchanged, so not a single investment was superfluous.

During the eight-year period, a large number of photogrammetric operators have made first steps in using computers and have become acquainted with the methods of analytical photogrammetry. Their transition to other photogrammetric systems (analytical or digital) would be very easy because the most difficult part of their training has already been completed.

If the fact that digital geodetic map is the most important prerequisite for LIS establishment is kept in mind, it can be stated that the final goal has been achieved. Due to the original development, digital photogrammetric mapping is now exclusively used for the new projects in Yugoslavia. Persistent and consistent development of computer aided mapping gave new life to the generation of obsolete analog instruments. The essence is the fact that the final product of computer aided mapping on analog instruments does not lack in quality compared with the product of digital photogrammetric mapping on analytical plotters. This fact, of course, does not exclude the necessity to procure new photogrammetric systems, but it certainly makes the situation of LIS establishment easier.

The world development of the digital photogrammetric mapping shows that users do not like to change the software environment they are familiar with. This requires the leading manufacturers of photogrammetric equipment to provide interfaces to software made by other vendors (LEICA DS 2000/3000). This also makes another confirmation that the investment in original development is justified, because the present users of the MapSoft software would not have to change their software environment when the time for transition to other photogrammetric systems comes.

4. THE SOFTWARE CONCEPTION

The developed software for computer aided mapping is based on the following assumptions :

- The software is a complete working environment separated from computer operating system. For each operation special software system is designed to meet all the requirements of a single workstation.
- The software is intended for surveying and photogrammetric engineers who do not need previous knowledge in informatics. Having respect for methods known in standard practice, the software combines in the best way possible, experience of the existing personnel and the advantages of computer aided photogrammetric mapping.
- The software respects the existing laws and regulations in real estate cadastre, as much as possible.
- Data acquired during the process of photogrammetric measurement are stored in a specially designed relational data base. The data base management system is integrated within software.
- User interface (menu system, data input, active software status, messages, answers, etc.) is designed in a same manner in all program units.
- Help is provided through on-line help and printed manuals.

The following technical requirements has been imposed to the software:

- the software works under MS DOS operating system;
- size of each program unit is limited to 640 Kb of RAM;
- 80x87 math coprocessor is required.

During eight-year period of the software development some other requirements appeared:

- the software has to be extended for operation in multiuser environment under NOVELL network operating system;
- for efficient operation of modules that are requiring graphics, 2Mb of RAM are recommended, 1Mb of which is used for disc caching.

4.1 PPCSoft software system

The basic purpose of this software system is computer support to analytical orientation of photogrammetric stereo model and to numerical restitution on analog stereoplotters. Currently, this software is mainly used for model orientation, because digital photogrammetric restitution has replaced numerical one.

Although the software conception was established already in 1987, it so far remained unchanged until nowadays, ie the current software version used is still 1.0. During model orientation, the software enables the following:

- analytical relative orientation using y-parallax measurements;
- analytical absolute photo model orientation using spatial transformation;
- calculation of final photo model orientation elements considering different construction characteristics of instruments used (Wild A7, A8, A10).

Special attention within software development is paid to the procedure for analytical absolute orientation of photo model. For gross error detection, "Data Snooping" method is applied. Stochastic data model assumes that model coordinates are not correlated and that they all have weight one, whilst coordinates of the control points have different weights. The procedure is designed using ergonomically developed functions. These functions, using menus and dialogues, help operator to measure control points, to perform adjustments, to check the results and to browse and edit input data efficiently and easily. Control points for the whole project are available at any time, since they are stored in a single data base created for that project.

Within numerical restitution PPCSoft enables:

- point measurement in static mode with manual or automatic point numeration,
- measurement of points in dynamic mode that can be controlled with time and distance criteria,
- browse and editing of measured data.

After orientation has been completed, the measured data are represented with absolute (object) coordinates. Otherwise, model coordinate system is used.

Considering that all the data are integrated within a single data base, PPCSoft enables export of the following data categories:

- list of all control points for the whole project;
- list of measured points in absolute coordinate system;
- reports on orientations of all photo models within a project with the following information:
  - general information on photo model (photo model label, operator, instrument label, origin of the coordinate axes, axes scales, etc.),
  - final orientation elements,
  - corrections and weights for all observations in adjustment,
  - statistical parameters on the achieved accuracy.

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Project: TEST1                    Photo scale: 13000  Camera cons.:153.13 [mm
Operators:Mitic & Mihajlovic      Instrument:A7-626   Photo model :101-102
Trig. sect.: 7E30, 7D30           Map sheet :DL-2     Map scale   :  5000
Start pos:500.00 500.00 450.00    Axis type : AerFot  Axis scale  :1.0 1.0 1.0

| Last point | 1234 |  530.89 |  456.67 |  265.12 | Reg start |

S-Start  R-RegStart O-Orijent  M-Measure  L-List  I-Info  H-Help  E-End

                          Absolute orientation
     NT        VY     VX     VZ      WY    WX    WZ      DY    DX    DZ

     T210      0.22   0.15  -0.01    1.5   1.0   0.1     0.9   0.9   1.3
     T211     -0.02  -0.15  -0.06    0.2   1.0   0.3     1.0   1.0   1.4
     T209      0.04   0.13   0.03    0.2   0.8   0.2     0.9   0.9   1.2
     V1013    -0.15  -0.15   0.12    1.0   1.0   0.7     1.0   1.0   1.3
     V1012    -0.13  -0.12  -0.04    0.8   0.7   0.2     0.8   0.8   1.2

   M0 =   11.25    MY =   17.49    MX =   13.45    MZ =    5.67   [cm]

Command > Absolute orientation is correct ? (Y/N)
```

Figure 1 : Report on results after absolute orientations

Tho whole application is integrated and can be started with a single command. All executables of the software system occupy less than 1Mb of disk space, and the whole installation occupies less than 2Mb.

4.2. BINEM software system

The main purpose of this software system is a computer support to block aerotriangulation using independent models. Considering the character of the task, the system is divided into three integrated software sub-systems:

- IFM sub-system for support to independent model measurements
- AFM sub-system for analytical generation of photo models using comparator measurements

- BIN sub-system for block adjustment and data analysis

Instrumental model generation (BINEM-IFM): The purpose of this software sub-system is complete computer support to measurements of independent models for block aerotriangulation. The most significant functions that are supported during photo model measurement are (Figure 2):

- analytical relative orientation based on indirect measurement of y-parallax using ω- movement,
- analytical determination of projection centers using measurements on "resau" plates at end positions of z-axis,
- listing and editing of measured data,
- on-line controls during measurement:
  - status of the measured points,
  - control of the point numeration,
  - control of connections of neighbouring photo models in row,
  - preliminary adjustments of rows for checks of control points, etc.

The most significant functions that this subsystem provides are:

- transformation of monocomparator or stereo-comparator measurements to photo coordinates and creation of data base containing photo coordinates,
- analytical generation of independent photo models with efficient tracking of results and reports,
- data export using simple ASCII formats for data input to other software packages.

Block adjustment using method of independent models (BINEM-BIN): This sub-system is the most important part oft the BINEM software system. Efficiency of the block aerotriangulation adjustment has been achieved by efficient detection and elimination of gross errors during measurement or analytical generation of photo models. Additionally, special data organization provides interactive adjustment which yields extremely good results during the stage of detection of remaining gross errors.

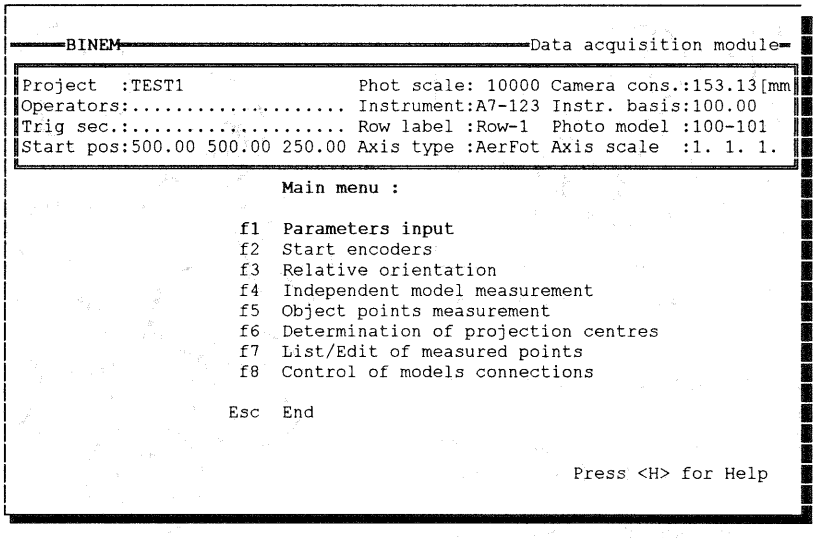

Figure 2 : The main menu of the BINEM-IFM software subsystem

The result of independent model measurements within a project is a data base. The contents of this data base can be exported to file using simple ASCII format. This can be used for data input to other photogrammetric software systems for block adjustment. If the adjustment is to be done using BINEM software, then export of data is not necessary, since direct access to the data base is provided within all BINEM modules.

Analytical generation of independent models (BINEM-AFM): Method for analytical generation of independent models has been used very rarely and it has lost its significance with the appearance of the bundle block aerotriangulation. However, in the midle 80-ies analytical generation of photo models was still alternative to measurement of independent models. Therefore, this method is equally supported.

The most significant facilities at the stage of preparation for block adjustment are :

- automated generation of photo models list,
- formal and logical data control before adjustment,
- selection of parameters that are of significance for adjustment,
  - number of iterations,
  - correction for earth curvature,
  - maximum point frequency (numer of model where of a point),
  - weights for measurements of projection centres,
- generation of fictitious models for incorporation of additional observations in block adjustment (Mihajlović, 1986): information on object geometry, surveying measurements of distances, directions, azimuths and coordinate differences, etc.

The most significant options that are available during data adjustment are:

- classical block adjustment (separated horizontal-height adjustment) with at least two iterations,
- robust block adjustment using Danish method for detection of large gross errors (Krarup, 1983)
- selective "Data Snooping" as a method for detection of small gross errors (Foerstner, 1984)
- efficient data adjustment
- graphical representation of the following results:
  - vectors of corrections,
  - structure of the banded matrix of reduced normal equations
  - disposition of the points and models within block (Figure 3) etc.
- elimination of observations from adjustment with limited adjustment, etc.

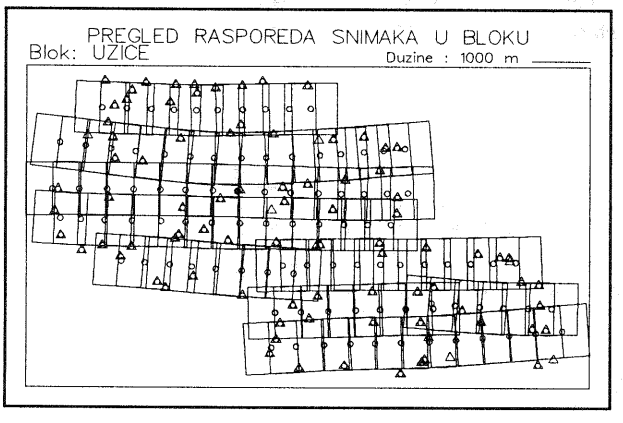

Figure 3 : Disposition of the points and models in block

On completion of the adjustment and accepttance of the results, the software enables:

- transformation of coordinates for object points measured during measurement of independent models,
- calculation of final elements of absolute model orientation considering different types of analog instruments,
- sorting of points according to map sheet division, etc.

The final conception of the software system was established in 1989. Version 2.3 from December 1991 is currently in exploitation. Installation of the software system occupies 5Mb, of which 4Mb is for executables. All programs works under MS DOS in real mode.

4.3. MapSoft software system

Digital photogrammetric restitution is a crown of the development of the computer aided support to analog photogrammetric instruments. Considering that in Yugoslavia in 1991 there were no practical experiences in the field of digital cartography, it was not possible to solve the problem of the digital photogrammetric restitution separately. In other words, if digital technique would be used only in photogrammetry, and the other participants in technological process (cartographic editing, parcel area calculations, map reproduction, map maintenance within cadastral units, etc.) would still use analogue technique, then the results would be incomplete. Therefore, in the middle of 1991, the concept of the Digital Geodetic Map (DGP) was established in Yugoslavia. The DGP was imagined as a system composed of three vital components: data base, software and hardware. Data acquisition, processing, analysis, handling and maintenance of the geodetic map contents were the main purposes of this system. Software support to this system was named MapSoft.

The MaSoft is a software system which is designed for all participants in a technological process of geodetic map production and maintenance, as well as for various map users who have based their activities on geodetic maps as spatial data sources. The basic software conception is shown on Figure 4. All methods of digitization have been supported. Digital photogrammetric restitution takes the central position.

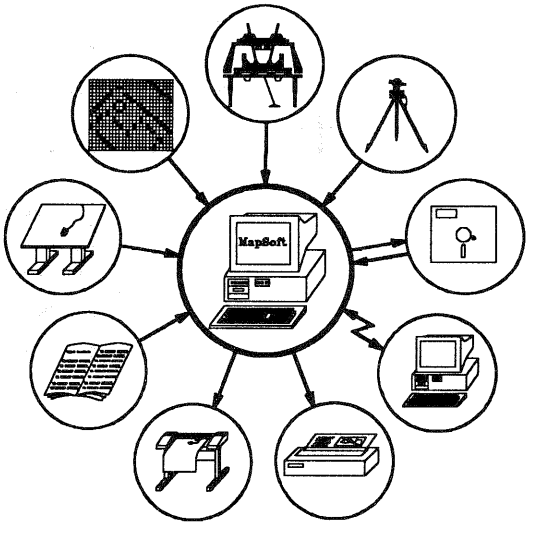

Figure 4 : Basic conception of the MapSoft

The most important functions supported within restitution are:

- on-line transformation of model coordinates to object coordinates;
- data acquisition for DGM horizontal representation with automatic assigning of graphic and layer attributes and creation of topology;
- DTM data acquisition:
  - measurements of spot heights, profiles and grid,
  - contour digitization using the following criteria: distance, time, curvature (tube) and combination of the previous ones,
  - digitization of structure lines with automatic creation of topology;

- unlimited movement of the measuring mark in space (automatic pan);
- rotation of the drawing for κ-angle from absolute orientation of the photo model.

Before photogrammetric restitution starts it is necessary to perform analytical absolute orientation of the photo model by using PPCSoft software. It means that PPCSoft is practically preprocessor of the MapSoft software system. Similar preprocessors have been developed for other methods of digitization also.

- DigiSoft for digitization using tablet digitizer,
- DigiScan for on-screen digitization of the scanned map.

In addition to previously mentioned functions, all other functions for universal DGP support are also available:

- display functions,
- editor functions,
- COGO functions for various constructions of DGP elements using coordinate geometry,
- tools for geometric corrections of terrain objects with regular shape, etc.

Operator supervises map compilation in standard cartographic form all the time. Simultaneous update on the several workstations of the same data base (same project, even same map can be update) in multiuser (network) environment is supported. Therefore, it is possible to do cartographic editing on separated workstation without photogrammetric instrument connected, in order to increase efficiency of the photogrammetric workstations.

5. FUTURE ACTIVITIES

The development of the major components of the software for computer aided photogrammetric restitution in Yugoslavia has already been finished. The confirmation of the success achieved is the fact that the developed technology is currently used on 18 analog stereoplotters. Also, large sale restitution started to be carried out exclusively in digital form since 1992. This development has als been a necessary impulse to completely transit to the digital technology of production and maintenance of large scale geodetic maps in Yugoslavia.

Further optimization of the software support to digital geodetic map and development of application modules for DGP utilization are the goals of further activities. This includes support to digital maps for infrastructure systems, land consolidation, urban planning etc. In the field of computer aided photogrammetric restitution, activities will be :

- improvement of functions for DTM data acquisition and processing,
- development of functions for digital orthophoto production,
- development of interfaces for linkage to software shipped with analytical and digital photogrammetric systems.

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