COST-EFFECTIVE DIGITAL PHOTOGRAMMETRY

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ABSTRACT

Digital photogrammetry is currently acknowledged to be the way for the future and we live in time of transition to digital photogrammetry. Digital Photogrammetric Workstations (DPW) do not only solve the standard photogrammetric tasks, but data in digital form also introduce a new quality in the use of photographs. DPW solution brings much higher productivity into photogrammetric production, but this technology has been considered to be very expensive. This paper clearly states cost factors of digital photogrammetry. The use of standard personal computers seems to be cost-effective way for future systems. A live example of such solution based on our product PhoTopoL is outlined. PhoTopoL can meet many needs for digital photogrammetry, image-analysis, remote-sensing, and GIS software in one package. It offers end to end solution for the map production as well as image analyses. This paper also presents the use of PhoTopoL in real practice within middle-scale example.

1 Digital photogrammetry

Analogue stereoplotters using optical and mechanical components were used for map making for decades. Later they were widely replaced with analytical stereoplotters. It means that many of these optical and mechanical components were substituted by computer solution. It increased flexibility and productivity. But it still was mechanical equipment joined with computer. Digital photogrammetry currently offers fully computerized solution.

Digital photogrammetry is currently acknowledged to be the way for the future. We can say that we live in time of transition to digital photogrammetry. The main advantages of the digital approach have been discussed extensively and are well known. Digital Photogrammetric Workstations (DPW) do not only solve the standard photogrammetric tasks, but data in digital form also introduce a new quality in the use of photographs, especially concerning automatic evaluations of the imagery.

Digital images enable to use special algorithms and technologies developed within other disciplines, such as computer graphics, data visualization and computer vision. Automatic evaluation of Digital Elevation Models (DEM), feature extraction and image interpretation, automatic computation of relative orientation, image enhancement and radiometric corrections belong into this field.

The demand for digital photogrammetric systems has also been influenced by related information and design systems, such as GIS/LIS or CAD. Effective combination of vector and raster data seems to be the biggest advantage of new systems. Superimposition of digital photographs with existing GIS databases allows to take advantage of both raster- and vector-based GIS for data analyses and map production. System flexibility and universality is given by handling data of various sources in one instrument. Though it is increasingly difficult to draw the line between photogrammetry, remote sensing and GIS areas.

2 Cost factors of digital photogrammetry

It is quite clear that DPW solution and new features are able to bring much higher productivity into photogrammetric production. But DPW has been considered to be very expensive technology. Cost factors influencing digital photogrammetric production can be divided into four groups:

1. Computer hardware and system software
2. Image processing hardware and software
3. Maintenance fee
4. Cost of labour

2.1 Computer hardware and system software

Most of DPW currently run on UNIX workstations with RISC processors and special-purpose graphics accelerators. These workstations are quite expensive (reasonably equipped – from 30,000 US$ upwards) and are usually used only for these special photogrammetric tasks. UNIX software is also very expensive in common as well as the use of UNIX environment increases expenses for training and wages of operators.

Therefore to reduce the expenses on computers and software, new digital photogrammetric systems should run on a standard personal computer with minimal attachments. The advantages of RISC processors and special-purpose accelerators over Intel CISC processors and PC plug-and-play architecture are rapidly disappearing. Pentium and new P6 processors offer adequate power for most of DPW tasks.

The use of standard personal computers creates the possibility to utilize them for other tasks and to increase the effectiveness of hardware as well as software expenses. Standard PC software is also cheaper in common and the use of standard Windows environment (MS Windows, Windows 95, Windows NT) is for many people well known and quite natural. So that the use of standard PC environment can also decrease expenses for operator training. The same look and feel of photogrammetric software with usual editors and computer tools also brings higher productivity to their utilization.

2.2 Image processing hardware and software

The biggest problem of digital photogrammetry seems to be scanning and image data storage, because of its size. Primary data collection is still nearly always made by conventional photogrammetry, when digital photogrammetric systems need a conversion of the analogue image to digital format by scanning. Prices of the equipment for this purpose can range from 2,000 US$ to 300,000 US$.

One aerial black-and-white photograph in 23 x 23 cm format scanned on 1000 DPI represents about 100 MB image data. In the case of true colour images it is even three times more. It means that in the case of stereo pair and its orthophoto it is necessary to have 1 GB of free disk space for true colour raster data processing. Image compression techniques and modern computer storage devices (such as optical disks and high capacity tapes) can currently solve the problem with storage capacity for data archives but it still remains need for fast and large disks for data processing.

Another problem seems to be the price of DPW software. Current professional systems are mostly running in UNIX environment. So that it is very difficult to find system, which offers full range of functionality with price up to 10,000 US$. To take full advantage of digital photogrammetry, it is necessary to support main photogrammetric tasks (such as digital orthophoto processing, automatic generation of DEM and stereoplotting) as well as close link with full-featured GIS system. The use of standard personal computer environment also enable users to use all advantages of current software integration and increases effectiveness of software expenses.

2.3 Maintenance fee

There are no mechanical/optical moving parts and instruments in digital photogrammetry, thereby eliminating and reducing maintenance difficulty. But hardware and software maintenance fee should be considered. From this point of view standard PC environment greatly reduces maintenance fee. Plug-and-play PC architecture enable users smoothly upgrade power and capacity of computer (processor, memory, disks, other peripherals). It is also possible to move special equipment and software for photogrammetry to new (and more powerful) computer and use older hardware for other tasks.

UNIX operating system and environment was considered more reliable and well-suited for large computational tasks and big data management, which is necessary for image processing and digital photogrammetry. Windows NT have currently the same reliability and provide also sufficient features for large computations and big data management. Software for Windows 95 and Windows NT can currently utilize standard system functionality such as preemptive multitasking, multithreading, advanced OpenGL graphics etc.

2.4 Labour costs

Even though a lot of operations can be done automatically there is still a lot of manual work. Computer programs have to be operated, control points and fiducial marks have to be located and all automatic operations have to be followed by verification and editing. Reducing of the cost of hardware and on the other hand high cost of labour with the increased demand for spatial data for GIS will cause desire for other automatic operations.

At this moment most photogrammetric operators are not skilled in the management of large data volumes (GBytes of data in computer files) and the complex manipulation of the DPW software. The operator can be less skilled in photogrammetry but should be more skilled in computer operations in the future. It is likely that a new type of photogrammetric specialist is to emerge. They will be experts in software and file manipulation who has developed expertise in the photogrammetric operations. The use of standard PC environment can significantly help in technology utilization, make photogrammetry more wide-spread as well as decrease expenses on labour training and wages.

3 PhoTopoL

In this section we would like to introduce a live example of cost-effective solution for digital photogrammetry based on our product PhoTopoL. PhoTopoL is a powerful low-cost software application developed by Help Service – Mapping Ltd. (Prague, Czech Republic) for production of precise maps from aerial photography. The system is supplied in three versions with gradual levels of functionality. The most advanced version of the system provides all main functionality of DPW mentioned above.

PhoTopoL performs orthorectification to remove geometric distortions and the effects of terrain relief displacement in aerial photos. PhoTopoL also produces Digital Elevation Models by correlation of stereo pair. Its stereo plotting capabilities provide very good tool for preparation and updating digital maps and DEMs. More over full-featured GIS system (TopoL) is included in PhoTopoL and all data are captured directly for the use in TopoL GIS. PhoTopoL is running on a standard personal computer in MS Windows environment.

3.1 Image orientation

PhoTopoL supports image stereo pair parameter settings, such as internal and external orientation elements, and image orientation calculations. Absolute orientation of a photo or a stereo pair can be calculated on the basis of following methods:

- standard relative orientation and spatial transformation of a DEM into ground coordinates
- Bundle Adjustment method

To calculate an absolute orientation of one image or a stereo pair, it is necessary to provide following parameters:

- camera parameters (calibration protocol), focus length, coordinates of fiducial marks
- flight altitude (approximate, not quite important), which is usually printed on the photograph
- four fully specified (X, Y, Z coordinates) control points at least

3.2 Orthorectification

PhoTopoL provides orthorectification functionality. Orthorectification removes the effects of relief displacement and imaging geometry from aerial photos. Rectification can be done in our system pixel by pixel or by triangles where users are able define the size of triangles. In that case the system works faster but one has to take into account the relief of scene and the influence of generalization when it is substituted by network of triangles. Grey values or colours can be calculated by Nearest Neighbourhood method or by Bipolar Interpolation. Orthorectified imagery has broad applications in both photogrammetric and GIS fields.

3.3 Digital Elevation Models Generation

PhoTopoL DEM Generation version enable users to generate DEMs automatically from image stereo pairs. Special algorithm for image stereo pair correlation was developed for PhoTopoL in Laboratory of Computer Vision at Czech Technical University (see [7]). By using these stereo correlation algorithms, the system is able to extract elevation values from image stereo pair.

The system uses pyramid method during correlation process. The output are single points with information about results of correlation stored in joined external database. These values can serve for selection of points used for created DEM. PhoTopoL is equipped with own module for small- and middle-scale DEM generation, which is able transform point collections as well as contour lines into raster DEM form. Afterwards Raster DEM forms primary base for orthorectification process in all versions of the PhoTopoL system.

PhoTopoL provides also direct link to ATLAS system, which is another Czech product developed for specific tasks of DEM creation, edit, calculations, analyses and visualization. ATLAS enables users to create flexible elevation models for generating contour lines from selected points. This module includes a powerful engine for adding and editing breaklines and obligatory lines, perspective three-dimensional views, profile calculations etc.

3.4 Stereo Visualization and Editing

The most advanced PhoTopoL configuration gives stereo plotting capabilities. In this configuration the system uses two monitors. The primary one is for PhoTopoL control screen (with menus, dialogs and drawing canvases) and the secondary one is used for stereoplotting. This configuration requires to upgrade personal computer with special stereovision equipment (in our case with StereoGraphics Crystal Eyes and video adapter Number Nine Imagine 128), which is supplied with the PhoTopoL Stereo system.

PhoTopoL Stereo enable users to view and edit in stereo. The system offer possibility to register X, Y, Z coordinates of new points using floating or fixed cursor as well as update position of points provided by other input techniques, which are supplied within TopoL GIS system. The data are captured and manipulated directly into GIS system which offers immediate attribute collection as well as full scale of GIS functionality (such as edit tools, analyses and other visualization methods).

3.5 TopoL GIS system

PhoTopoL not only supports links to various GIS systems, but it also includes special version of TopoL GIS system. TopoL is a general Land/Geographic Information System software which allows the creation, maintenance, analysis and visualization of geographical data. This original Czech product integrates the traditional vector-based GIS system with a powerful tool for image processing and remote-sensing. It is especially strong in its ability to create composite black-and-white or colour raster-and-vector output – for example, property boundary outlines superimposed on an aerial photograph.

TopoL GIS is capable of handling both vector and raster data equally well from a display, query and functional perspective. Additional non-spatial information can be attached to this graphical data and stored in local or external databases. Extensive care was focused on topology and support for topographic structures of vector data. The system provides wide scale of vector and raster data manipulation and analyses methods, which includes vector data overlays, database analyses as well as image processing and multispectral data classification.

4 PhoTopoL applications

We would like to present some examples of PhoTopoL use in real practice. In this section we describe in short various applications of the system (forestry, aerial photoplans, regional management). We also present in detail one middle-scale project of orthophoto map creation performed within our data capture department.

4.1 Application overview

We were able to sell 15 installations of the system within three months after its introduction to software market. The system is currently used in forestry (Lesprojekt – Forest Management Institute) and regional management (District council Klatovy) as well as in firms specialized to photogrammetric processing (e.g. NADIR). The system is also prepared for sale into other countries, because it is available in English, German, and Italian version. Our official distributors in Slovakia, Germany, Italy, Switzerland, Russia, Latvia and Estonia are able to provide full support for our customers.

TopoL GIS system is currently considered to be the standard GIS system for forestry in the Czech Republic and it is also used for forest management in Germany and Italy. One of our biggest customers - Forest Management Institute - is currently using PhoTopoL especially for orthorectification of aerial photographs. These photographs are used as one of sources for the creation of forest management plans in the whole Czech Republic. Specialists in Forest Management Institute are also quite satisfied with stereo plotting capabilities of PhoTopoL.

Our subsidiary Help Forest have used PhoTopoL in several forest management projects for DEM generation and orthorectification. Land management office of District council Klatovy started to use PhoTopoL for the creation of orthophoto maps. These maps will be used directly as one source for decision-making in regional management as well as for quick evaluation of maps which are currently utilized in land modification projects. NADIR photogrammetric company have started with the use of PhoTopoL for large-scale projects, especially in the preparation of aerial photoplans.

4.2 Nymburk project

Nymburk is one district of the Czech Republic. It has about 880 square kilometers of land size. The project was performed for District council Nymburk. The goal of the whole project was to create orthophoto maps of the whole district in the scale 1 : 10,000. These maps will be used for map evaluation and updating as well as next source of data for decision-making.

66 colour aerial photographs in the approximate scale 1 : 25,000 was used as the main source for the project. These photographs were scanned into true colour TIFF raster files with 600 DPI resolution. Approximate size of one image was about 90 MB. After scanning images were converted into internal format of PhoTopoL and stored on optical disks.

The PhoTopoL internal images can be stored in tiled format which enables very efficient access to the disk while reading and writing raster data. This is very important because it dramatically shortens the time of rectification. PhoTopoL also uses special caching system for reading and writing data, which enables to have in memory only that part of raster which is to be used.

Existing DEM for the Nymburk region was used as a next data source for the rectification. DEM developed in military topographic center, which is available for the whole Czech Republic, was utilized. This DEM is a grid model and the size of grid is 100 m. While importing into PhoTopoL the model was resampled with bipolar interpolation of elevation values into new grid size of 20 m.

The world coordinates of control points were collected before calculation of absolute orientation. These points were stored within TopoL GIS vector data block (layer). They were picked up from the maps in the scale 1 : 5,000.

The whole region was divided into several subregions. These ones were designed to fit the map sheets with small overlay. First of all, the absolute orientation of all photographs in the subregion were calculated. Then the orthophoto rectifications in PhoTopoL's batch mode were run. After that the mosaic of the whole subregion was created from the rectified photographs. The resulting mosaic was cut into final map sheets.

This project was performed in March 1996. After all we are able to say that all process including scanning, image and DEM import, collection of control points, rectification, mosaicking and cutting into map sheets took about 10 days for two persons. PhoTopoL was run on PC computers equipped with Pentium 90 MHz processors, 16 MB RAM, 1 GB disk. Optical storage device was attached to one of these PCs and computers were connected within computer network.

5 Conclusion

This paper demonstrate that PhoTopoL can meet many needs for digital photogrammetry, image-analysis, remote-sensing, and GIS software in one package. It offers end to end solution for the map production as well as image analyses. Decreased price of both hardware and software solution lets to have more these low-cost personal systems and work very effectively and quickly, which means higher productivity for digital photogrammetry. Standard personal computers and environment protect hardware and software expenses and increase their effectiveness.

The inclusion of TopoL GIS in the PhoTopoL system offers large base for direct use of photogrammetric data and results in other geodata analyses. This paper presented the use of PhoTopoL in real practice. We described middle-scale project in detail as well as various applications (forestry, aerial photoplans, regional management) in brief overview.

REFERENCES

[1] Ebner, H., Fritsch, D., Heipke, C. (eds.) 1991. Digital Photogrammetric Systems. Wichmann, Karlsruhe.

[2] Förstner W., Ruwiedel, St. (eds.) 1992. Robust Computer Vision. Quality of Vision Algorithms. Wichmann, Karlsruhe.

[3] Fritsch, D., Hobbie, D. (eds.) 1995. Photogrammetric Week '95. Wichmann, Karlsruhe.

[4] Nwosu, Z.A.: Digital Versus Analytical: A Matter of Photogrammetric Coexistence. International Journal for Geomatics, 10 (1), pp. 35–37.

[5] Pivnička, F. 1996. PhoTopoL - User's Guide. Help Service Mapping, Prague.

[6] Trinder, J., Donnelly, B. 1996. Digital Photogrammetry: What It Can Do and How It Will Affect the Future of Photogrammetry. International Journal for Geomatics, 10 (1), pp. 6–8.

[7] Werner, T. 1995. Epipolar correlation of image stereo pair. Internal report, Czech Technical University, Prague.

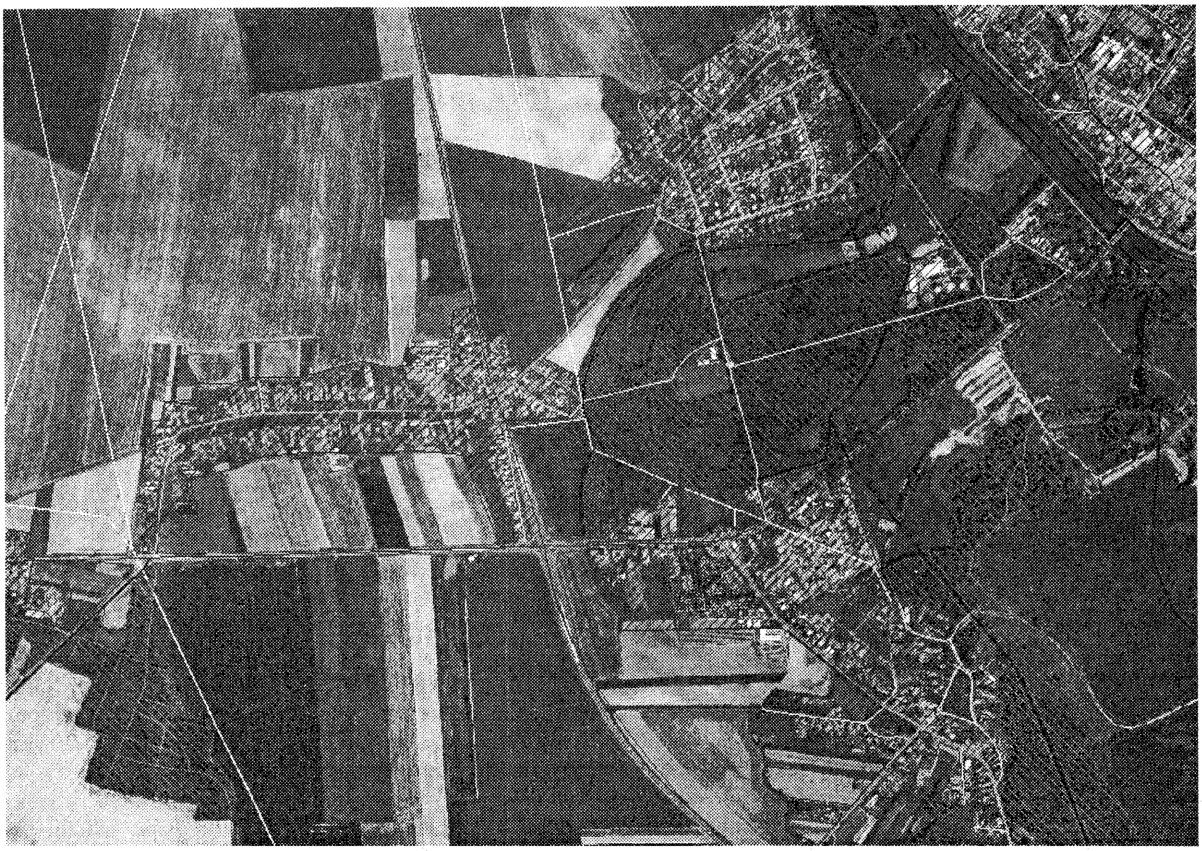

Figure 1: Orthophoto map from the Nymburk project.