DEVELOPMENT OF A PC-BASED
MODULAR PHOTOGRAMMETRIC SYSTEM

by

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The aim of this project is to develop a system for various photogrammetric applications. The required hardware is a standard PC. The main part of the system is a graphical user interface to handle the different applications. The system shall be modular, so that the user can decide which is important for him having the possibility to supply new modules later. In the beginning the system shall include a digital stereo plotter for point and graphic measurements, programs for bundle block adjustment (BLUH) and DTM computation (MODELL). Later developments can be to produce orthophotos and the connection to a GIS.

1. Digital Systems

It is an often quoted fact that the very fast development of computer technology offers increasing performance at decreasing hardware costs. Digital image handling is nowadays at the state of becoming easy and cheap enough to be used on low cost systems. Therefore the conditions are given for implementing advantages like for example image enhancement and automatic measurement into easy to handle photogrammetric software on small computers.
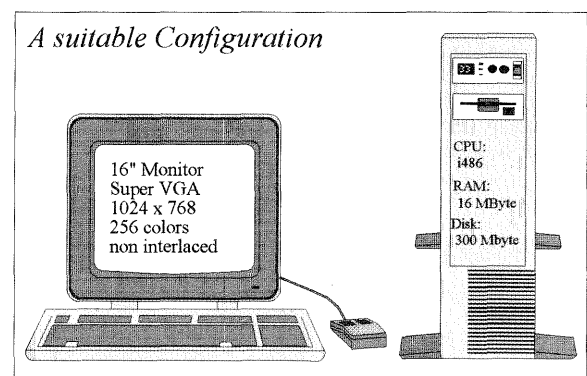
2. Hardware Concept

2.1 The Computer

Several platforms which meet the requirements are available: Apple Macintosh, IBM-PC and compatibles, Sun SPARC and compatibles, and NEXT-Computers. In the near future some new RISC-Systems may become an alternative.

Lowest prices and a very large number of installations world-wide make the IBM-PC - compatible the favoured machine. No other system has a comparable market of hardware components and software. The architecture is well documented and not (further) dependent on the support of a special company. The operating system DOS is very easy to handle compared for instance with UNIX on Sun

workstations. Other important software aspects are discussed in a chapter below.

Configurations can be varied in a wide range. Suitable CPU's are Intel 80386/80387 and 80486 processors at a frequency of 25-50 MHz. Onboard memory is available up to 64 MByte. Disk capacity reaches more than a GByte.

A suitable Configuration

16" Monitor
Super VGA
1024 x 768
256 colors
non interlaced

CPU: i486
RAM: 16 MByte
Disk: 300 Mbyte

A very important component for digital image handling and measurement is the display capability. The conventional way to get an image on a screen was to add a special video board and monitor to the system. Now the actual Super VGA cards delivered with most standard systems offer nearly the same features as the old and very expensive extensions. Today a home PC has the possibility of displaying images at a resolution of 1024×768 pixel with 256 colours simultaneously with an acceptable performance.

The costs for a minimum configuration differ between about 5000.-DM ($2800.-) for a noname system and about 15000.-DM ($8400.-) for e.g. a COMPAQ. Noname's are assembled and sold by little dealers, often using a lot of components one can also find in a computer of an established trademark. They are an excellent way of saving money without loosing to much performance.

2.2 Image Acquisition

CCD video cameras and suitable frame grabbers are available in a wide range. The market for terrestrial sensors with high resolution will expand in the next years. Nevertheless the most reasonable way to retrieve digital image data for measurement purposes today is to take conventional photos and digitise them on flatbed scanners. Advantages are the possibility of using all the potential of standard camera systems, digitising old material, building sections of interest at a high resolution with a minimised amount of data, etc. .

Low cost scanners are available for about 3000.-DM ($1700.-). The image area has a size of 20×30 cm^2 ($8" \times 12"$) which is sufficient for the most terrestrial cameras. Aerial photos can be partly scanned and later merged or oriented with only three fiducial marks. Physical resolution is 300-400 dots per inch, which means 60-80 μ pixel size. Taking subpixel measurement into account, a precision of 20 μ should be reachable. The effective accuracy can be increased for smaller photos (e.g. Rollei 6×6) by enlarging them during the necessary copy from a negative to a positive.

2.3 Presentation of Results

Everywhere the PC measurement workstation is not connected with a GIS or any peripheral hardware via a network, additional effort has to be made in order to obtain presentable products and documents.

Laser printers have a very precise output concerning text, vector and raster graphics. Photos can be printed for demonstration purposes. Prices are low today for a standard format and resolution. Pen plotters mostly have a larger format and are better suited to draw line maps. Cheap alternatives are needle printers and inkjets. The choice hardly depends on the given tasks. Minimum costs should be about 1000.-DM ($600.-).

3. Software Concept

3.1 Operating System

The most popular operating system for PC's is the Microsoft DOS. It is not expensive and quite easy to install and handle. The supply with compatible software is immense. Nevertheless there are some restrictions given preventing DOS from being usable for great tasks without extension. Problems mainly arise from limits of the memory management. The compatibility to all the processors of the Intel line enforces a standard operating mode, the so called "real mode". A maximum address space of one megabyte and a 16-bit segmentation method require much extra effort while programming with large data structures. There are several extensions available providing solutions to the memory problem. So called DOS extenders switch the processor into another mode with other addressing schemes. They must be shipped with every software developed for them. Some compilers are specially designed for this kind of operation. Another way is the 'simple' use of expanded memory via standard drivers and interface routines. They supply more RAM, but have at least the same segmentation problems.

Also Microsoft "WINDOWS" is an operating system extension. Mainly it is a window environment for DOS, comparable to e.g. Sun's OpenWindows. It guarantees - while running - full compatibility to DOS applications, even if they are programmed 'with every trick'. Multitasking and data exchanging is implemented for DOS and WINDOWS applications. The processor runs in the so called "protected mode", protecting one application from being disturbed by another, using all available memory and swapping on disk when necessary.

3.2 Software Development

Even though WINDOWS has some disadvantages, for instance less execution speed, it is a powerful base for software developers. The window routines, implemented as at execution time dynamically linked libraries, guarantee a unified appearance for each application. The complete hardware driver management is done by WINDOWS, therefore the software development is mostly hardware independent. Routines for graphics - vector and pixel oriented - are available in a wide range.

The interface to WINDOWS is delivered with Microsofts "WINDOWS Software Development

Kit", containing also a set of helpful tools. Programming language is C, in the near future C++.

Several other distributors offer software packages for building WINDOWS applications. BORLAND for example sells a C++ and "Turbo Pascal". GFA-Basic has to be mentioned, but will not be further supported.

3.3 Compatibility in Future

Today it seems that nearly all software innovations in the DOS-PC market are implemented as WINDOWS applications. The reason for this great success is the full compatibility with older DOS programs. For the typical DOS user the 'change' to WINDOWS is very easy and without the risk, that his old software will not run. He has the possibility to grade up his system step by step, beginning to use the features of the new environment.

The future of WINDOWS depends on wether Microsoft is able to establish the new 32-bit operating system "Windows NT" before IBM has too much success with OS/2 2.0, which is very inexpensive and should be compatible to existing WINDOWS and DOS applications. Windows NT is an attempt to create an operating system which is able to run on different computer architectures. The first two being supported will be the Intel line (80386 / 80486 / *80586*) and the R4000 chipset from MIPS on a DEC platform. The actual WINDOWS as well as DOS will be implemented as own modules. The portation of WINDOWS applications to the new 32-bit structure should be possible without to many changes. The interface routines of Windows NT have already been published. In many details they are identical to the actual SDK.

4. A Modular System

At universities software development is made for many different purposes and by a permanently changing crew. Also students often have to deal with programming for their exercises and diploma thesis. The result of all this is that there are a lot of software parts, written in a lot of different languages, basing on different machines and operating systems, baring any possible standard.

Providing an open and standardised environment is the aim of the system discussed in this paper. The task is not only to define rules and interfaces for

software compatibility. A set of photogrammetric and geodetic tools will be supplied to the user, who can add his own components. A continuos development should let the system grow by time. In this context the digital imagery is the leading subject, which does not mean that conventional photogrammetric evaluation will be refused totally.
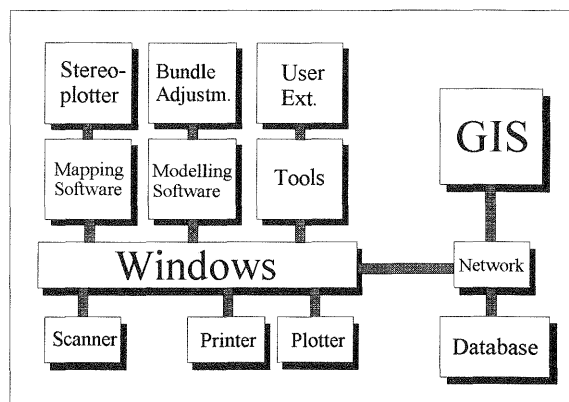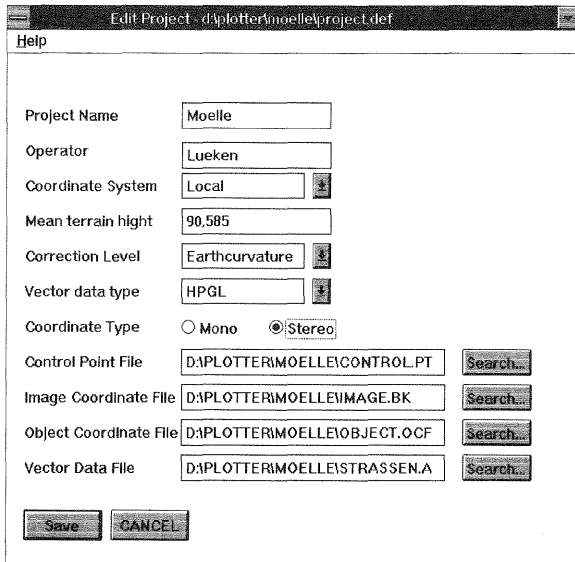

Many software parts will be in an operational state. Therefore they can be made available to users outside of the universities. The consequent modularity allows a very individual configuration for each task and an easy upgrading later on.

Care has to be taken on the interfacing to existing commercial software packages. On one hand there are the widely spread tools for word processing, painting and data presentation. On the other hand are the more specialised CAD, data bases and - very important - the GIS. ARC/INFO from ESRI will be supported. It depends on future requests of users, which other software connections have to be implemented.

5. Applications

The main applications of the photogrammetric system are the measurement of image coordinates and the further processing of this data, the computation of digital elevation models (DEM) as a first step for creating othophotos and the generation of cartographic information for geographic information system.

For a fast evaluation or only a simple measurement all modules in this system can be used without defining a project. If an evaluation consists of more images a project shall be defined. The project handles the images with orientations, used sensors, the used files etc. The next picture shows the input mask for the editing of projects.

Project Name	Moelle
Operator	Lueken
Coordinate System	Local
Mean terrain hight	90,585
Correction Level	Earthcurvature
Vector data type	HPGL
Coordinate Type	○ Mono ⦿ Stereo
Control Point File	D:\PLOTTER\MOELLE\CONTROL.PT Search...
Image Coordinate File	D:\PLOTTER\MOELLE\IMAGE.BK Search...
Object Coordinate File	D:\PLOTTER\MOELLE\OBJECT.OCF Search...
Vector Data File	D:\PLOTTER\MOELLE\STRASSEN.A Search...

Save   CANCEL

5.1 Mono/Stereo plotter

The plotter programs include the editing of the used sensor. Before any measurement program can be started at least the interior orientation has to be computed, to calculate the relationship between the pixel and the image coordinate system.

The output of the measurement program are image coordinates which can be processed for example with a bundle block adjustment to compute object coordinates. Another result of the block adjustment are the orientation parameters of the images which can be used to calculate images in epipolar geometry.

5.2 Block adjustments

The most rigorous and accurate method of block adjustment is the bundle block adjustment used in the program systems BLUH and BINGO. Input data are photo coordinates which can be measured with the digital plotter.

5.2.1 Bundle orientation with BUNOR

The program BUNOR was implemented to compute the orientation of a stereo pair. The geometry of the photos may be perspective, panoramic or high oblique and can be selected for each photo separately so the program is not restricted to photos with an identical geometry. It is not necessary to have initial photo orientations. In case of high oblique photos or for photos with a narrow opening angle which is frequently the case

in close-range or macro photogrammetry the initial tilt must be given approximately. Furthermore the program offers the possibility of self calibration by providing additional parameters. Optionally it performs an automatic error reduction after data snooping.

5.2.2 Program BLUH

The program system BLUH is a block adjustment program for aerial photographs. It is a modular system to guarantee an optimal user friendly handling.

At the computation of strip coordinates and approximate photo orientations data snooping is used to locate blunders. The method of robust estimators is able to detect not identified blunders in the bundle block adjustment. Additional parameters determine systematic image errors.

Additional programs exist for pre-processing and analysing:

- transformation into different coordinate systems
- correction of distortion, refraction, earth curvation
- comparison of different data sets
- analysis by covariance

5.2.3 Program BINGO

BINGO is a program sytem for aerotriangulation and close range photogrammetry. It is a combined adjustment of geodetic and photogrammetric measurements.

A simultaneous camera calibration for focal length, principal point as well as 24 additional parameters are included. Baarda's data snooping is used for error detection for all observations. Approximate orientation data and point coordinates are calculated by a pre-processing program.

5.4 DTM computation with MODELL

MODELL is a program for the computation and evaluation of digital elevation models. Input are 3-dimensional coordinates covering the area in different densities depending on the agitation of the ground.

Possibilities to get these input data with the digital plotter are

- single point measurement in single or stereo mode
- creation of grid data by correlation

Other sources can be from

- measurement of single points, profiles or grids with analytical plotters (e.g. Planicomp C or P series)
- measurement of single points or contour lines in topographic maps
- direct measurement of points or profiles at the object

After the computation of the digital elevation model the following applications can be used

- computation of profiles, contour lines, slopes, expositions
- output of surface models
- overlay of contour lines with slopes
- computation of superficies, cut areas, statistics etc.

6. Further Developments

6.1 Image Processing

In future developments image processing tools shall be included in the system. These components shall be suited to photogrammetric tasks which are for example

- image rectification
- filter operations
- edge extraction

6.2 Correlation

For many applications a correlation can be used for the point measurement. A simple application can be the measurement of the fiducials marks for the interior orientation. As the fiducial mark has a known pattern the correlation in this case leads to an accurate result.

The relative orientation is although an application which can be solved by correlation. Increasing the number of points for the relative orientation leads to a higher accuracy.

The correlation is although the most effective method to get an efficient number of input data for the computation DEM.
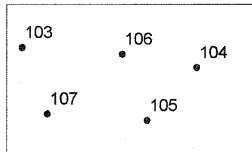
6.3 Orthophotos

As the calculation of DEM's is already one aim in this system the next step must be the creation of digital orthophotos.

Orthophotos can be used for example in GIS as background information. They can be the basis for digitizing to update maps. Orthophoto maps can easily be overlayed with contour or thematic information.

6.4. Geographic Information System

One important aim is the integration of a GIS. Photogrammetry is the most efficient tool to deliver the enormos amount of data to build up a GIS and to update an existing GIS.

The measured elements will be overlayed with the digital image. It shall be possible to measure only "spaghetti" data and correct it later in the GIS, or to directly combine the graphic information, containing points, lines and areas, during the measurement with thematic information.

Geometric information	Thematic information			
	ID	Type	Height	Girth	Age

Geometric information	ID	Type	Height	Girth	Age
103 106 104 107 105	103	Oak	10.23	0.95	23
	104	Beech	12.34	0.88	15
	105	Beech	10.45	0.78	12
	106	Oak	5.67	0.56	15
	107	Birch	12.80	0.66	11

The planned interface is for ARC/INFO (ESRI), which has a function for the input of these elements (GENERATE). The thematic information can be connected with the JOINITEM function.

7. Conclusions

The intention to develop this new digital photogrammetric system is to combine an operational and well equipped workstation with an interface to existing software and to scientific and user programming. For university purposes it has to be a low cost system which can be upgraded with hard- and software for special tasks or higher performance. A consequently open structure has to be provided in order to derive a wide acceptance. Modularity on every level should guarantee a good compatibility for future computer environments.

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