Photogrammetric digital image processing at Carl Zeiss

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ABSTRACT

Photogrammetric digital image processing is geared to the applications of digital photogrammetry. After a brief introduction to digital photogrammetry, the PHODIS photogrammetric digital image processing system from Carl Zeiss is presented. A detailed description is given of the new PHODIS ST digital stereoplotter. The paper is rounded off by an overview of further PHODIS components.

1. DIGITAL PHOTOGRAMMETRY

A clear, comprehensive definition of the term *Digital Photogrammetry* (DP) does not exist to date. However, it could be outlined as follows: the application of photogrammetric methods to digital images using general image processing techniques. Additional components are the generation and output of digital images. The outstanding feature of DP is the strict separation of image generation, applications technology and image output. This offers the benefit of being able to use specially developed or existing instruments for image generation and output, while the applications do not depend on what instrument is used.

The images are generated by various digital sensors which are used both for *object scanning* and *image scanning*.

While digital object scanning from satellites seems a suitable method of handling specific, thematic applications, it has not yet experienced a breakthrough in topographic applications. Until now, aircraft-based digital object scanning has only been used in special applications, e.g. in thermal surveys. A digital equivalent capable of competing with the classical aerial survey camera in every respect cannot be expected to emerge in the near future. In terrestrial photogrammetry, on the other hand, and here in industrial photogrammetry in particular, the first successful results have been achieved in the use of digital cameras for object scanning, e.g. with the UMK SCAN.

Sensors for digital image scanning, of course, are already being employed in several image scanners such as PS1 PhotoScan. This instrument permits fast conversion of analog images into digital image data virtually without any loss of information, which means that this technique will probably set the standard in digital image generation in the next few years to come.

Classical tasks such as aerotriangulation, image orientation, surface modelling, orthoprojection and stereoscopic plotting, both of the topographic or thematic type, have to be implemented by DP to accommodate the different applications. DP, however, does not yet cover the full range of applications provided by analytical photogrammetry. This is partly due to the fact that a fully satisfactory approach has not yet been found for some aspects of DP. The storage capacities and data transfer rates of networks and input/output instruments, for example, still need to be improved. In addition, the algorithms are not always equally suitable for different types of application. The least squares matching method (LSM), for example, may well be sufficient for the measurement of fiducial marks, but this is not necessarily the case for automatic surface reconstruction.

Image output is another essential part of DP. The output of digital photogrammetric data is understood to comprise not only the mere display on the monitor, but primarily the reconversion of this data from the digital into the analog form. For the purposes of data processing, a difference is mainly made between raster and vector data. However, the combined output of digital image data (= raster data) and vectors is frequently required. Suitable output instruments are colour-separating laser raster plotters or colour plotters, e.g. BARCO BG3x00 or IRIS.

2. PHODIS

The name PHODIS means *PHO*togrammetric *D*igital *I*mage processing *S*ystem. It stands for the DP product line from Carl Zeiss and encompasses the previously mentioned DP components. The following applications are currently implemented in PHODIS:

application	product name
image generation	PS1 PhotoScan
fully automatic surface modelling	TopoSURF
digitial orthoprojection	PHODIS OP
digital stereoplotter	PHODIS ST
image output	e.g. BG 3x00

One of the main ideas behind PHODIS is to provide the user with an efficient, dedicated instrument configuration at exactly the right time by taking into account trends in technology and application. Time-tried principles and applications have been retained - although they may need to be adapted to the digital form of the images - and have been extended by robust and, if possible, automatic image processing methods. Image orientation, for example, includes fully automatic procedures for the determination of the interior and relative orientations. Existing products such as PHOCUS are integrated into PHODIS, permitting the use of the same application software on analog, analytical, and digital plotters from Carl Zeiss.
A major design feature of PHODIS is its modular structure. Modules such as interior orientation or the image pyramid are used in different applications.

3. THE DIGITAL STEREOPLOTTER - PHODIS ST

A digital stereoplotter is required for stereoscopic photogrammetric plotting in DP. The name of the instrument offered by Carl Zeiss for this purpose is PHODIS ST. Due to the connection of photogrammetric plotting software such as PHOCUS or CADMAP, it permits the familiar working environment to be retained. Prior to a detailed description of PHODIS ST, the various basic components and methods involved will be discussed.

3.1 Components and methods

In simple terms, a digital stereoplotter consists of hardware and software components. The hardware comprises a high-performance computer with graphics monitor, keyboard, mouse, and several hard disks. This is supplemented by a device for the stereo capabilities of the hardware, summarized under the term *stereo eyewear*, and a photogrammetric 3D input device for floating mark movement with function keys, in short the *photogrammetric cursor*. In principle, however, a 3D input device may also comprise the classical components handwheels, foot disk and foot switches. The software is responsible for the control of the photogrammetric cursor, for image orientation, for stereoscopic image display and floating mark control, and for the communication with the application program. The latter may be a photogrammetric data acquisition and plotting system, or a suitable geographic information system (GIS) module.
The methods of stereo display are usually the techniques on which most interest is focussed. This essentially refers to stereo image display with floating mark movement and to stereo viewing. Further aspects are, for example, zooming and contrast enhancement which are both covered by known algorithms in image processing.

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3.1.1 Stereo image display

Two different, frequently used techniques will be discussed here in more detail as examples of stereo image display. In the simpler method, a screen-sized section of the stereo pair is displayed and retained on the screen, and the floating mark is moved across this model section. This is termed as the *fixed-image-moving-cursor* principle (fimc). The advantage of this principle is its easy implementation, as only one simple graphic element, the floating mark consisting of two parts for the left and right images, needs to be moved in the stereo scene. Therefore no exacting demands are made on the graphics hardware. In the more complex case, the stereo scene is moved freely and continuously, i.e. with a sufficient frequency, across the screen. The floating mark is located at the centre of the screen as in the customary eyepiece. This is called the *moving-image-fixed-cursor* (mifc) principle. The requirements made on the hardware are incomparably higher here, especially if, for example, a colour scene scanned with 15 [microns] is involved. For both techniques, the azimuths of the images with respect to each other need to be taken into account. In the stereo display techniques described here, this is usually achieved by projecting the image sections constituting the stereo model into an epipolar image plane by a preprocessing operation which requires a large amount of computation. Afterwards, one and the same object in the left and right image of the stereo szene is located in the same image line, but in different image columns. The difference between the image columns corresponds to the known x-parallax. This preprocessing operation generally means a loss of both time and storage space due to the necessity of generating epipolar images. It would therefore be a great advantage if ways and means could be found of rotating the images with respect to each other on-line on the monitor.

3.1.2 Stereo viewing

Two different methods are also frequently encountered in stereo viewing, and will be described here in greater detail as examples. In both cases the operator uses special eyewear and is able to move freely in front of the monitor, and both techniques employ polarization. The difference consists in how the polarization method is used. In the first technique, the screen is covered with a switchable, polarizing film, and the operator wears polarizing eyewear similar to sunglasses. The display of the right and left images in their respective range of polarization and the interaction with the polarizing eyewear provides the image separation and thus the stereoscopic effect. Since polarized light is supplied to the eye, however, this technique involves a marked light loss. In the other technique, slightly larger eyewear is used, with each of the lenses containing two layers of liquid crystals. These crystals are oriented by the alternate application of voltage, with the result that each layer acts like a polarizing filter. Since the two directions of polarization are perpendicular to each other and since the polarization takes place simultaneously, the effect is the same as that of a camera shutter for the eye, i.e. the image information is only supplied to one eye at a time. This is called the liquid crystal shutter (LCS) principle. Synchronization with the display system ensures that the left image is supplied to the left eye and the right image to the right eye at a high frequency, e.g. 60 [Hz], thus achieving the image separation required. The special feature of this technique is the fact that the eye receives unmodified light. The light loss caused by the liquid crystals is significantly lower than in the method initially described.

3.2 Implementation

PHODIS ST currently runs on computers from Silicon Graphics Inc. (SGI). The 3D input device of the digital stereoplotter is the *P-mouse* with similar functions as the familiar P-cursor, but does not require a digitizing tablet. Hand wheels, foot disk and foot switches can be connected. The system uses two standard monitors, one for menu control and the second for stereo image display. Stereo viewing is performed using the previously described LCS method. The display of both monitors is flicker-free when viewed through the LCS stereo eyewear. Stereo image display is based on the fimc and mifc principles described above, each characterizing a different product stage. In addition to this available algorithms and appropriate computer hardware allow to rotate the images with respect to each other on-line on the monitor. This way the mifc technique is possible without time- and space-consuming epipolar preprocessing for every stereomodel. PHODIS ST also offers fully automatic interior and relative orientations, Heipke 1993. These automatic procedures enable the user to access the stereomodel without any manual measurements.

4. FURTHER APPLICATIONS

Apart from the digital stereoplotter, further applications have been implemented in PHODIS and will be presented briefly in the following.

4.1 Image scanning - PS1 PhotoScan

Image scanning is already possible in the recently launched PS1 PhotoScan, Faust 1990, a joint development of Carl Zeiss and Intergraph Corporation, USA. This photogrammetric flat-bed scanner digitizes positive and negative transparencies in black-and-white or colour up to a size of 260 [mm] * 260 [mm] into square pixels with a side length of 7.5, 15, 30, 60, or 120 [microns]. The instrument has been specially tailored to meet DP requirements.

4.2 Generation of elevation models - TopoSURF

Digital stereo pairs can be used in TopoSURF for the fully automatic derivation of a digital elevation model (DEM). TopoSURF comprises preprocessing, fully automatic DEM derivation, DEM editing capabilities, quality data and visualization tools. At the proprocessing stage, the interior and exterior orientation elements of the images can be either determined or imported. The images are then reprojected into an epipolar image plane - a process called normalization, in which allowance can be made for image corrections necessitated by distortion, refraction and earth curvature. This is followed by the generation of image pyramids for each normalized image. The images at the different pyramid levels are then taken as a basis for fast point extraction by so-called interest operators, resulting in interest pyramids. In the fully automatic DEM derivation, the interest pyramids are used for feature-based matching to determine iteratively 3D point clusters, from which a very dense, regular rectangular grid is derived by means of robust finite elements. Additional information on break lines and cut-out areas can be called in for the DEM computation, e.g. from the PHOCUS data base. The editing capabilities permit visually supported, subsequent editing of cut-out areas. Known individual heights within a cut-out area can be incorporated for local recomputation of the finite elements used, thus permitting updating of the DEM. The quality data provides local information on the quality of the elevation data determined. Optimum fields of application for TopoSURF are open terrain, sparsely built-up areas and small-scale image material in general. The resulting DEM can be directly used for orthophoto computation.

4.3 Orthoprojection - PHODIS OP

Orthoimage generation in a production-oriented environment is the function of PHODIS OP, Kresse 1993. Digital orthoprojection ensures that the generation of orthoimages is free from process errors. Filtering methods adapted from image processing, for example, permit several orthoimages to be

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combined into large mosaics without any visible separation lines between the individual orthoimages involved. This local image processing may be preceded, for example, by global histogram adjustment. The orthoimages or orthoimage mosaics computed by PHODIS OP can be employed by PHOCUS PM as image material for data acquisition.

4.4 Data output - BARCO, IRIS

The output of digital image data with or without vectors and text is implemented within PHODIS by the integration of the laser raster plotters from BARCO Graphics, Belgium, and colour plotters from IRIS Corporation, USA, Kresse 1993. The output instruments have different applications. The IRIS colour plotters permit the fast output of colour images in particular, e.g. orthoimage mosaics, for the compilation of work copies in small quantities. The BG 3x00 (x=7,8,9) laser raster plotters from BARCO, on the other hand, are ideal for the production of printing copies. Both instruments feature a raster image processor (RIP) from BARCO which permits the raster and vector data obtained e.g. from PHOCUS PM, to be combined at the plotting stage. The output instruments accept PostScript data, for example, and can be integrated into a network.

5. CONCLUSIONS

As things stand today, the benefits and drawbacks of DP can be outlined as follows:
One definite benefit is the extremely stable image geometry which remains unaffected by temperature and humidity. The interior orientation only needs to be restored once. Image changes such as contrast enhancement, local and global image operations, geometric transformations and image combination (mosaics, neutralization, marking of concealed image areas) can be performed without difficulty. Image generation by vector/raster superimposition and the generation of simulation models open up a wide variety of new applications. Due to the automization of procedures such as DEM generation, interior orientation, relative orientation, and batch processing, DP is gaining increasing importance in practical work. Finally, the output on the monitor permits the integration of DP applications into GIS.
This must be set against certain drawbacks: in viewing, DP offers less convenience with respect to brightness and contrast than the eyepiece and photo. Reflections and ambient influences may cause disturbance in the field of view. The resolution in the field of view on the monitor of a digital stereoplotter is approx. 25 times lower than the resolution in the equally sized field of view of the eyepiece in an analytical stereoplotter.
A vast potential for future DP applications lies in the increased use of algorithms adopted from image processing and computer graphics in combination with the geometric and mathematical models of photogrammetry. Special mention should be made here of the automatic extraction of buildings, Braun 1993.
To sum up, digital methods in photogrammetry can be said to provide a useful addition to the existing techniques. They permit the user to switch from analytical to digital photogrammetry as required during the production process. Digital methods are used in applications where extensive procedures can be replaced by full-fledged automated processes: in DEM and orthophoto generation, and in image orientations. Analytical methods, on the other hand, are employed in cases where continuous and concentrated measuring and interpreting by the operator are still indispensable: in the acquisition of planimetric data and attributes for map production and geographic information systems. All relevant data generated by these products are interchangeable. Photogrammetric data capture systems such as PHOCUS and CADMAP support as well the analytical stereoplotters Planicomp P-series including VIDEOMAP as well as the digital stereoplotter PHODIS ST. This way the photogrammetric products of Carl Zeiss enable the user to

work in a homogeneous environment of digital and analytical systems which guarantee highest efficiency for every task.

6. REFERENCES

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