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PHODIS Innovations

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ABSTRACT

The contents of this paper are the new applications and functions in the digital photogrammetric image processing system PHODIS. The report on news in PHODIS starts with new functions in PHODIS Base which represents a set of functionalities common to all PHODIS applications. This is followed by a short description of the new, rollfilm-capable photogrammetric scanning system PHODIS SC. Automatic aerotriangulation is implemented in the new PHODIS AT. For DTM-generation, the new tool PHODIS TS applies an integrated approach of preprocessing, automatic DTM-derivation, and postprocessing in a stereo editing environment. The paper concludes with a description of the new model PHODIS ST 10 of the digital stereoplotter.

1. INTRODUCTION

A digital photogrammetric system is supposed to offer to the user the full range of functionality required for production. This starts with the analog to digital (A/D-) conversion of analog images. Based on oriented images, applications such as topographic data acquisition, DTM-generation, and orthoprojection follow. For the purpose of orienting images, methods including aerotriangulation, absolote model orientation, and spatial resection are applied. Finally, the results of production are digital data and map sheets of any form.
These processes represent known procedures in Photogrammetry. There is, however, a specific potential of power of digital systems over analog or analytical systems which is the possibility to generate automatic measuring procedures. Such functionality uses the digital information contained in images in order to perform measurements.
The following focusses on the implementation of these possibilities in new applications and functions in PHODIS. Advantages in the use of digital photogrammetry (DP) are shown.

2. PHODIS

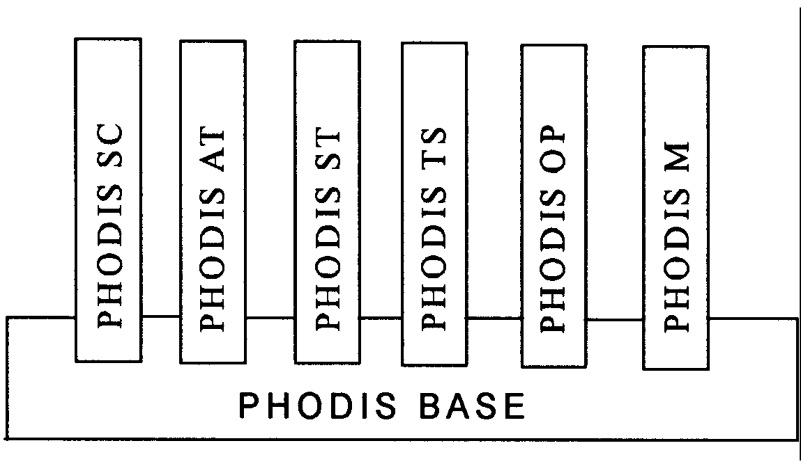

Figure 1: PHODIS product overview.

The first step of Carl Zeiss into digital aerial image processing was in 1989 with the presentation of the PS1 PhotoScan photogrammetric scanner (Faust 1989). The extension to a digital photogrammetric image processing system was done in 1991 through the presentations of the digital orthoprojection system PHODIS OP (Mayr 1991) and the system TopoSURF (Krzystek 1991) for the automatic generation of DTM using one stereomodel. The DTM-generation applies a fully automatic measuring

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method. This capability is one of the main features of DP. The generated DTMs were primarily used in orthophoto-generation. The introduction of the PHODIS ST digital stereoplotter opened the way to do data acquisition on such a device as well. Based on this package, new features and robust automatic procedures are implemented in new PHODIS applications. Figure 1 gives a schematic product overview of PHODIS and expresses the common base.

2. 1 PHODIS Basis

2.1.1 Automatic interior orientation (AIO)

The automatic interior orientation procedure is integrated into PHODIS Base (Willkomm and Dörstel 1994) which is an essential part of every PHODIS application (see figure 1). The method searches the fiducials by correlating a fiducial pattern with the image in a strategic approach. This way it determines the coordinates of the fiducials in the pixel coordinate system of the digital image (Schickler 1995). AIO is capable of recognizing the rotation of the image in the file. There are 8 situations possible. By localizing an unsymmetry pattern in the image it is possible to determine the situation of the image in the file. Furthermore, AIO can detect if the image is a diapositive or a negative. The robust estimation of the transformation parameters from the pixel coordinate system into the photo coordinate system contains criteria which allow the process to automatically either accept or neglect the results. AIO comes prepared for a variety of aerial cameras.

2.1.2 Automatic relative Orientation (ARO)

The stereo model setup is done either in a one-step procedure, applying the bundle solution for one model, or it is carried out as a two-step procedure with relative and absolute orientations. The latter procedure is commonly used e.g. in analytical stereoplotters. The process of relative orientation is based on the determination of conjugate points, so-called tie-points. This task can be performed in DP by an automatic process and is called the *automatic relative orientation*. Such a principle is integrated in PHODIS. It is composed of several steps the keywords of which are *image pyramids*, *feature extraction*, *feature matching*, *feature tracking*, and *robust parameter estimation* (Tang and Heipke 1994, 1993). ARO reduces the required time for interactive work with the system thus freeing up the operator. Due to the large number of conjugate points, e.g. 200, there is a high redundancy in the adjustment process. This ensures stable results, and, provided that good measurements were possible, one can obtain stereomodels with residual parallaxes of about 3 to 5 µm - a range of values which is comparable to results from relative orientations on analytical stereoplotters. However, the redundnacy usually is an order of magnitude higher in ARO. The absolute model orientation is reduced to the manual determination of ground control points. This procedure is called the manual bundle orientation (MBO) in PHODIS. Tie-point measurements of ARO are imported into MBO as additional observations.

2.1.3 Interfaces

The technology of digital photogrammetry is - with the exception of the scanning system - based on algorithms only and thus based on computers. All applications are software solutions only. The scanner is the only hardware required. The common perception of software is that it has the property of being adapted and extended easily. To a certain extent this is correct. For the user it has the advantage that he can solve special integration tasks himself, if he has access to appropriate interfaces. For this purpose an *open system* is required which allows access to all user-relevant information. PHODIS achieves this by default as it comes with open interfaces to its libraries for import and export of photogrammetric data. Data exchange can take place directly, or via ASCII-files or binary files. The user has the opportunity to access e.g. image data, ground control data, camera data, project data, and model data. With an extra library it is possible to get access to the command syntax of the PHODIS ST digital stereoplotter with the possibility of superimposing colored vectors in the stereomodel.

2.2 PHODIS SC

The requirements for a photogrammetric scanner contain technical and application-specific aspects. Important technical features of such a device are geometric and radiometric quality as well as the quality of color reproduction. From the point of view of the application, the following items are of special interest:

- The possibility to *operate the scanner without human interaction* over a longer period of time
- The generation of *photogrammetric digital images* for the direct use in other applications

This type of functionality is implemeted in the new photogrammetric scanning system PHODIS SC (Mehlo 1995). The operation without human interaction is possible through the *autowinder*, a retrofittable rollfilm attachment to the scanner base unit. This device allows the use of uncut rollfilm. The user is able to scan images from the roll film in an arbitrary order. The limiting factor is the available disk space. Otherwise the scanner can process in unattended mode. The potential connection to an image archiving system opens the possibility of a highly production-oriented scanning system. This way huge data volumes as used e.g. in automatic aerotriangulation can be handled and processed. The generation of *photogrammetric digital images* can be achieved in a postprocessing step. Here automatic processes are gathered and started as batch jobs. Such processes can be e.g. the generation of image pyramids, the automatic interior orientaiton, or histogram modifications. Storage of flight information and the generation of an overview image are done as well in this step.

2.3 PHODIS AT

One of the main features of DP is the automation of measuring processes by the use of image processing techniques. This has made possible the development of the automatic aerotriangulation (AAT). AAT is presented as a new member of the PHODIS family of applications in PHODIS AT (Mayr 1995). The basic approach of conventional aerotriangulation consisting of the steps *block definition*, *measurement*, and *block computation* remains the same in AAT. However, within block preparation and measurements many changes took place. The method of block computation is unaffected by AAT. Existing bundle block adjustment programs can be continued to be used in AAT. Block preparation in AAT uses as input data the flight identification of the images, the image numbers, the approximations of the coordinates of the projection centers, and the approximate values of the orientation angles κ. These data determine the geometry of the image block approximately. The block is inspected visually using a wire frame representation of all images in the block. During the block preparation in conventional aerotriangulation the block is tied together by interactively *selecting images*, *selecting tie-points to-be-determined*, and *pugging*, i.e. doing the *point transfer*. In AAT the block is tied together in the measurement phase automatically.
Prerequisites for automatic measurement in AAT are image pyramids. The connection between the images of the block is done automatically in the higher (lower resolution) pyramid levels. This step is called the *generation of the topology* of the block. The algorithm applied is a modified automatic relative orientation. Due to the fact that only higher pyramid levels are involved, this step can be done for the whole block. Ground control points and new object points are measured manually in the original images. The methods of least squares matching or feature based matching are applied as

measurement techniques in manual measurement. The manual measurement mode is part of PHODIS AT and allows the measurment of any type of point e.g. for the purpose of quality control measurements and repeated measurements of already measured points.

2.4 PHODIS TS

The automatic generation of digital terrain models (DTM) is almost a standard feature of a DP-workstation. The elevations are derived by a matching process which can be considered as robust and field proven. The DTM-generation is done with PHODIS TS. It contains the components *digital stereoplotter*, *DTM-verification* and *TopoSURF*.

2.4.1 Digital stereoplotter

The functionality of the digital stereoplotter is used as the tool for model setup. It also enables this application to perform interactive DTM-preprocessing and DTM-postprocessing which in combination represent the DTM-verification. The ability of superimposing colored vectors in stereo offers the visual inspection of the DTM itself. Thus, for an environment for DTM-generation the digital steroplotter is required.

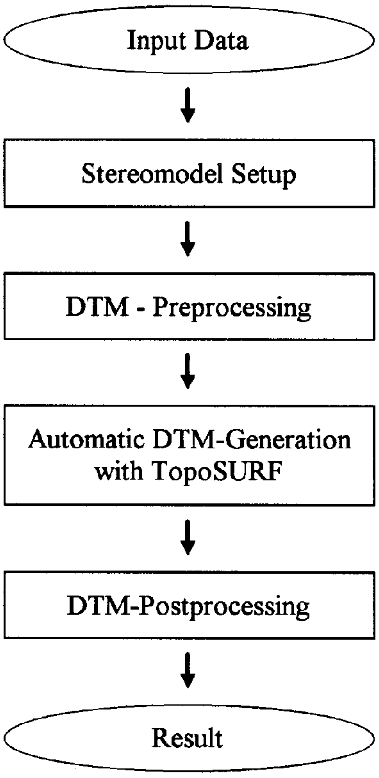

Figure 2: PHODIS TS main components.

2.4.2 DTM-Verification

This component of PHODIS TS kind of triggers the main work flow in automatic DTM-generation. DTM-verification requires a stereomodel in which, in the DTM-preprocessing step, three-dimensional morphological data are collected. The following morphological features are of special interest.

- Points of singularity
- Break lines
- Cutout area polylines

Morphological information is of importance to the DTM-generation process. It defines the constraints. within the derivation of the raster-DTM. DTM-postprocessing, better called quality control of the DTM, takes the resulting raster-DTM and analyzes it. It is possible to superimpose in color the DTM over the stereomodel. Visual inspection is then carried out. DTM-points can be picked, moved, deleted, measured additionally or simply inspected.

2.4.3 TopoSURF

The automatic DTM-generation is composed of the four steps image pyramid generation, feature extraction, feature matching, and robust finite element adjustment for the raster-DTM-generation. The procedure is discussed in detail e.g. in Krzystek 1991.
With this environment the user can easily collect additional information, start the automatic DTM-generation process, and perform quality control. The stereo capability is an essential part of this

concept. The raster-DTM can be used in PHODIS OP or for on-line elevation interpolation in PHODIS M.

2.5 PHODIS ST 10

The digital steroplotter PHODIS ST is now available in two models. In both cases the computer platform is Silicon Graphics (Dörstel and Willkomm 1994). The models differ in the way thy display the stereomodel.

- PHODIS ST 10 moving image fixed cursor (MIFC)
- PHODIS ST 30 fixed image moving cursor (FIMC)

PHODIS ST 10 is new. The images are moving in subpixel steps, and the floating mark is fixed in the center of the field of view. In addition to this capability, PHODIS ST 10 can display stereo scenes without having the requirement of pre-computing epipolar images. This saves computing time which, depending on the image parameters and computer speed, can be 30 or more minutes per image. It also saves disk space which can add up to several hundreds of megabytes of savings. Dynamic measurments especially e.g. contour line following are improved by this mode of displaying stereo scenes in a digital stereoplotter.

3. CONCLUSIONS AND OUTLOOK

PHODIS offers all appplications and function of a powerful digital photogrammetric product family. The homogeneous data flow is given on a standard hardware platform. Automatic procedures are integrated wherever they are robust. They are a fundamental part of the concept behind PHODIS.
Currently the requirement for huge amounts of storage capacities in some applications is still an open issue. The use of data compression methods might be a solution to a certain extent. However, non-reversible data compression techniques - and only those deliver acceptable data reduction values - can result in unacceptable loss of image information (Jaakola and Orava 1994). An alternative to this approach might be the implementation of a jukebox-based data archiving system. Storage media can be e.g. EXAByte, DAT, or rewritable magneto-optical CDs. Such a system could be connected to the scanner system which appears to be very helpful in unattended scanning mode. An alternative to a jukebox system can be a disk array. In conjunction with aerotriangulation, another use of such a mass storage device is feasible.
For the time being, the integration of field experience and further robust automatic procedures are important to DP. The operator is freed more and more from standard tasks in order to use his experience to take the decisions which an algorithm is not yet capable of.Automatic ground control point recognition, object extraction and line following in arial large scale images are amongst other subjects main areas of focus to the research community e.g. Heipke et al 1994, Gülch 1994, Fuchs 1995. PHODIS is prepared to implement such features.

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