Photogrammetric Week'93 Eds. D. Fritsch / D. Hobbie, Wichmann, Karlsruhe, 1993.

Digital orthophoto production with PHODIS

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ABSTRACT

PHODIS is the name of a product family for digital photogrammetry at Carl Zeiss. PHODIS ensures the complete digital data flow from the scanning of the photo to digital stereoplotting and the printing of an orthophoto map. PHODIS OP, the digital orthophoto component, is discussed in detail.

1. HISTORY

Orthoprojection instruments have a longstanding tradition at Carl Zeiss. Almost 30 years ago, in 1964, the GZ 1 Gigas-Zeiss orthoprojector was launched - the first series-produced instrument permitting stripwise rectification of photos. The Z2 Orthocomp analytical orthoprojector which has been on the market since 1980 is considered to be the most efficient system for orthophoto production so far.
Last year heralded the beginning of the era of digital orthophoto systems at Carl Zeiss with PHODIS. The experience gained in the design of analytical orthophoto systems during the past three decades has led to a further increase in performance in the production of digital orthophotos as compared with the time-tried instruments. The following describes PHODIS in greater detail.

2. THE MEMBERS OF THE PHODIS FAMILY

PHODIS is the name of a product family for digital photogrammetry from Carl Zeiss. PHODIS comprises

- the PS1 PhotoScan photogrammetric scanner for the accurate analog/digital conversion of aerial photos both at high speed and with high geometric and radiometric accuracy,
- the TopoSURF program system for the automatic generation of digital terrain models (DTM),
- the digital stereoplotter PHODIS ST for three-dimensional plotting in a stereomodel of digital images (Mayr, W., 1992),
- digital orthophoto computation PHODIS OP including all utilities required for a smooth work flow,
- the output of the complete orthophoto data on film or paper. Laser raster plotters from BARCO Graphics permit the exposure of the digital orthophoto on film as a preliminary stage in the orthophoto printing process. Ink-jet plotters from IRIS Graphics can be used for the direct output of black-and-white and colour orthophotos for small editions, and also for colour proofing prior to colour printing.

This list shows that, as an overall system, PHODIS ensures the complete digital data flow from the scanning of the photo to digital stereoplotting and the printing of an orthophoto map.

3. THE ORTHOPHOTO

The theory of differential rectification has been investigated and described in great detail in the past and requires no further substantiation here. Other demands which must be met by a production-oriented system are ease of operation and a flexible data flow.

For the computation process, PHODIS offers both a readily understandable user interface and the possibility of starting all modules from the system prompt level. The menues make it easy for the beginner to familiarize himself with the system, and they help those who use the system sporadically to find their bearings more easily. The modules started from the system prompt level can be combined into batch queues and, if necessary, can be processed overnight.

3.1 Input

The input data required by PHODIS comprises a digital image, the relevant digital terrain model, a variety of alphanumeric data and, if available, the orientation parameters for the image.
The digital image is normally scanned by the PS1 and can then be directly processed in PHODIS, without any need for format conversion. However, PHODIS also accepts images from other sources if the digital data is available in the formats TIFF, COT or RAW. RAW is understood here as a simple byte stream format where the data is arranged in rows.
PHODIS processes any type of DTM, provided it is in any one of the following formats:

- DTM points arranged in a rectangular grid as an ASCII file
- Any kind of arrangement of the DTM points as an ASCII file
- DTM generated by TopoSURF in the binary format.

The arbitrary arrangement of points is also called "Triangular Irregular Network" (TIN) and permits the incorporation of breaklines for optimum modelling of the terrain.
A major field of application of the digital stereoplotter PHODIS ST is DTM measurement. If TopoSURF is used for DTM computation, the stereoplotter merges perfectly with the data flow and provides a neat method of breakline measurement before TopoSURF performs the computation and, afterwards, of visually checking the resulting DTM and of remeasurement, if necessary. TopoSURF, PHODIS ST and PHODIS OP can be operated on the same computer, with the same data material and without conversion of the format.

3.2 Orientation

The alphanumeric input data for PHODIS OP mainly consists of the camera calibration data and any photo orientation data which may already be known. The orientation parameters can be specified as rotational angles, as a rotational matrix or as a PHOREX file, PHOREX being the exchange format for photogrammetric orientation data which is supported by all Zeiss systems such as PHOCUS, P-CAP and PHODIS ST. The possibility of reading in PHOREX data demonstrates the high level of integration in the Zeiss photogrammetric systems, permitting users of existing instruments to operate their equipment together with the new products without difficulty.
A predefined orientation can be directly used for rectification. However, this means that the data flow is uncontrolled and even gross errors may remain undetected. It is therefore advisable to use a predefined orientation only as an approximation for verification or remeasurement performed interactively on the monitor.
PHODIS offers an orientation measurement performed in two steps: the interior and exterior orientation. In PHODIS, the interior orientation can be measured either manually on the monitor or semiautomatically by an approximation measurement using only two fiducial marks. In the latter case, the orientation program finds the other fiducial marks in the digital image and then determines the position of all marks by a matching procedure.
The exterior orientation must be measured on the monitor. If the orientation data is known, the positions of all points stored in the control point file are marked from the outset by a circle. If the ori-

entation is being determined for the first time, the marking circles are not displayed until after the second point measurement, and their positions are then approximated with increasing accuracy in each further point measurement.

3.3 Rectification

For actual photo rectification, PHODIS offers all the standard interpolation techniques. The geometrical rectification of aerial photos can be performed either by the use of anchor points or pixel by pixel. The methods available for grey level interpolation are "nearest neighbour", "bilinear" and "bicubic" and the "Lagrange method". Due to the optimization of the algorithms used and the high computation speed of the Silicon Graphics computers, the simple interpolation methods need not be applied, thus keeping the computation times for rectification within acceptable limits. If the most precise interpolation method is used (pixel-by-pixel or bicubic), the rectification of one megabyte of orthophoto pixels in Silicon Graphics Indigo R4000 takes as little as 20 to 25 seconds. As a result, a typical orthophoto of 20 megabytes is computed within about 7 minutes.

3.4 Output

For the output and further processing of the orthophotos, PHODIS can generate raster data formats which meet the requirements of most applications:

- TIFF
- PostScript
- USGS
- SGI
- COT
- RAW
- CT

TIFF and PostScript are currently considered the most common exchange formats for raster data and are supported by virtually all renowned GIS products.
USGS is the format used by the US Geological Survey.
SGI denotes the image data format which is supported by all computers from Silicon Graphics Incorporated (SGI) and for which a large variety of digital image processing functions are available in the SGI world.
COT is the standard image data format in the Intergraph world.
As previously mentioned, the RAW format is the simple byte stream format permitting data transfer to virtually all other computer types.
Files in the CT format are used for data output to the laser raster plotters from BARCO Graphics or to the IRIS Graphics ink-jet plotters, provided they operate on a raster image processor (RIP) from BARCO. In both cases, raster and vector data can also be output in the PostScript format.

3.5 Output instruments

The digital data flow in PHODIS OP includes the production of repro material for the large-circulation printing of maps in black-and-white and colour as well as colour plots for small editions. The BG 3700, BG 3800 and BG 3900 laser raster recorders from BARCO GRAPHICS permit the high-precision exposure of large printing copies and are used in all fields of cartography. Both line maps and photo maps can be produced this way. PHODIS orthophotos can be directly

transferred from the SILICON GRAPHICS computers to the BARCO instruments which are equipped with a computer of their own, the raster image processor (RIP). The BARCO instruments can be fitted with an automatic film loading device which allows unattended overnight operation. The direct connection to film developing equipment is also possible. The large BG 3900 processes film formats up to 120 cm x 160 cm. Colour separation, raster data, raster angles etc. are managed by a control program on the SILICON GRAPHICS computer.
The 3024 and 3047 ink jet printers from IRIS GRAPHICS feature state-of-the-art dyeing technology which permits black-and-white and colour copies resembling normal photos to be produced up to a format of 86 cm x 118 cm. The throughput rate for a complete copy done in the largest format is approx. 45 minutes. The IRIS GRAPHICS instruments are used for:

- the production of small editions
- the fast output of high-quality hard copies from digital data bases
- colour proofing.

The latter denotes a colour matching technique for the subsequent printing of large editions using repro films produced by the BARCO plotters. For colour proofing, the IRIS GRAPHICS ink-jet printer must be equipped with the same RIP as the laser raster plotter from BARO GRAPHICS.

4. PRODUCTS BASED ON ORTHOPHOTOS

Orthophotos can be processed in many different ways. The digital methods offer a far greater variety of possibilities here than the earlier systems Z2 Orthocomp and, in particular, GZ1. The orthophoto products mosaic, orthophoto map and monoplotting will be discussed in the following.

4.1 Mosaic

Orthophotos can be fitted together with high geometric accuracy if all the input data is correct. Due to the different light conditions during the exposure of the original photos, however, the edges normally remain visible as a break in colour and brightness. Such an assembly of images is called a "puzzle" in PHODIS. It can be produced in a very short time but is inadequate for most applications. To improve this, PHODIS provides automatic matching of the brightness and colours along the image edges by interpolation of the grey levels in an overlapping strip. The resulting large orthophoto in which the edges of the individual images are no longer recognizable is called a mosaic. PHODIS matches the images so effectively that is is no longer necessary to place the separation lines of adjacent images along geographic lines in order to conceal any remaining differences. Mosaicking can be performed in PHODIS without operator intervention.
The generation of a mosaic eliminates restrictions in orthophoto production which have existed so far, and opens up a number of new applications.
Until now, an orthophoto has always been tied to the size of the aerial photo. Now, orthophotos can be produced regardless of the original aerial photo, e.g. in accordance with a given map size.
The size of a mosaic is only limited by the mass storage unit of the computer. A computer of sufficient capacity therefore permits the creation of national image data bases without map sheet lines, from which sections can be extracted as required at practically any scale.

4.2 Orthophoto map

An orthophoto map is produced by superimposing vectors on an orthophoto or orthophoto mosaic and offers a wide range of design options. The vector data may be limited to the map frame; they

may also be used for the annotation of the orthophoto or may even constitute the complete contents of a line map. In this case, the orthophoto provides supplementary background information for the line map.
PHODIS can read in and superimpose vector data from other systems e.g. PHOCUS. The PHOCUS PM-station permits raster and vector data to be checked together on the monitor and finally processed.

4.3 Monoplotting

The features of orthophotos are very similar to those of the original aerial photos: they offer up-to-the-minute data after a photoflight and contain a vast amount of information which is, however, unfiltered. These features can be utilized for

- map updating
- application-specific supplementing of maps and
- data acquisition for the creation of geographic information systems.

In monoplotting, the vector map is superimposed on the orthophoto on the monitor which permits specific objects to be copied to the vector map. This method is supported by several Zeiss systems. Full integration with PHODIS orthophotos is already possible for PHOCUS with the PHOCUS PM-station and for CADMAP. In both, the elevations of all points measured on the monitor are directly determined on the basis of the appropriate DTM, and the elevation data is filed as the third dimension.
Standard formats permit the PHODIS orthophotos to be read into other systems such as ARC/INFO and SICAD, where they are used for data acquisition by the monoplotting method.

5. SUMMARY

This overview shows that PHODIS can rightly be said to continue the tradition of Zeiss orthophoto instruments. Today, however, orthophoto production is no longer performed by an entirely independent system. Instead, the production of orthophotos is only one component in PHODIS, the system for digital photogrammetry, which covers the complete range from the scanning of aerial photos to the printed orthophoto map and to GIS applications.

6. REFERENCE

Mayr, W., (1992): Das photogrammetrische Bildverarbeitungssystem PHODIS, Vortrag zum PHODIS Workshop in Oberkochen, 25./26.11.1992.