Photogrammetric Scanners

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ABSTRACT

Photogrammetric scanners enable the application of digital photogrammetry in the field of digital compilation and interpretation of aerial images. There are some market requirements for a roll film capable scanner. Carl Zeiss fulfills these with its new scanning system PHODIS SC. The basic components of this new scanner and its integration into the digital photogrammetric system PHODIS are the contents of this paper.

1. INTRODUCTION

Digital images are the basis for the application of the technology of *digital photogrammetry* (DP). They are captured either by object-scanners, such as digital close-range cameras, or they are generated by converting existing analog images into digital images by the use of image-scanners. This latter approach is the specific interest of this paper. Image scanners are designed to accomodate aerial photographs and the high geometric demands of photogrammetry. A variety of photogrammetric image scanners is available on the market (Kölbl 1994). The increasing usage of DP in production is also influenced by the properties of the scanning device. In order to comply with future requirements, it appears to be a necessity that the scanning device possesses the ability to handle uncut original roll film. It should also be fully integrated into a digital photogrammetric image processing system and maintain its achieved quality. These generic demands are realized in the new PHODIS SC scanning system from Carl Zeiss. The remainder of this paper deals with this new system.

2. PHODIS SC

The modular design of PHODIS SC consists of three main modules. These are the *scanner*, the *roll film attachment*, and the *user interface*. The scanner module is called *SCAI* (SCanner with Autowinder Interface) and is designed as a table-top flatbed scanner for aerial images. It connects to a workstation as a standard peripheral device. The roll film attachment module name is the *Autowinder* and it enables the scanning system to be delivered in two models: SCAI with or without Autowinder. *SC-software* is the name of the user interface which forms the third PHODIS SC module. All operations except loading and unloading the scanner with images can be done via this interface. The scanner system is integrated into the PHODIS product family as PHODIS SC.

2.1 SCAI

SCAI is a new development, designed as a transmissive scanner and optimized to fulfill photogrammetric requirements. It can process either single, cut sheet film, glass plates, or original uncut roll film. The basic design regarding *mechanics*, *optics*, and *electronics* is explained in further detail below. The design was influenced by two requirements: to be able to handle roll film automatically and to be connected to a workstation as a standard peripheral device. These requirements made it necessary to design this device from scratch and in a different way to other scanners, e.g. the PS1 PhotoScan (Faust 1989). The main features of SCAI are:

- roll film capable scanner,

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- geometric resolutions: 7, 14, 28, 56, 112 and 224 µm,
- geometric accuracy better than 2 µm,
- radiometric resolution of 256 levels of grey in each of red, green and blue,
- largest area for scanning: 275 mm x 250 mm,
- color scans in one pass; monochrome scans possible,
- one-dimensional color-CCD-camera with three parallel linear arrays for red, green, and blue,
- diffuse illumination,
- PHODIS-like user interface.

2.1.1 Mechanical module

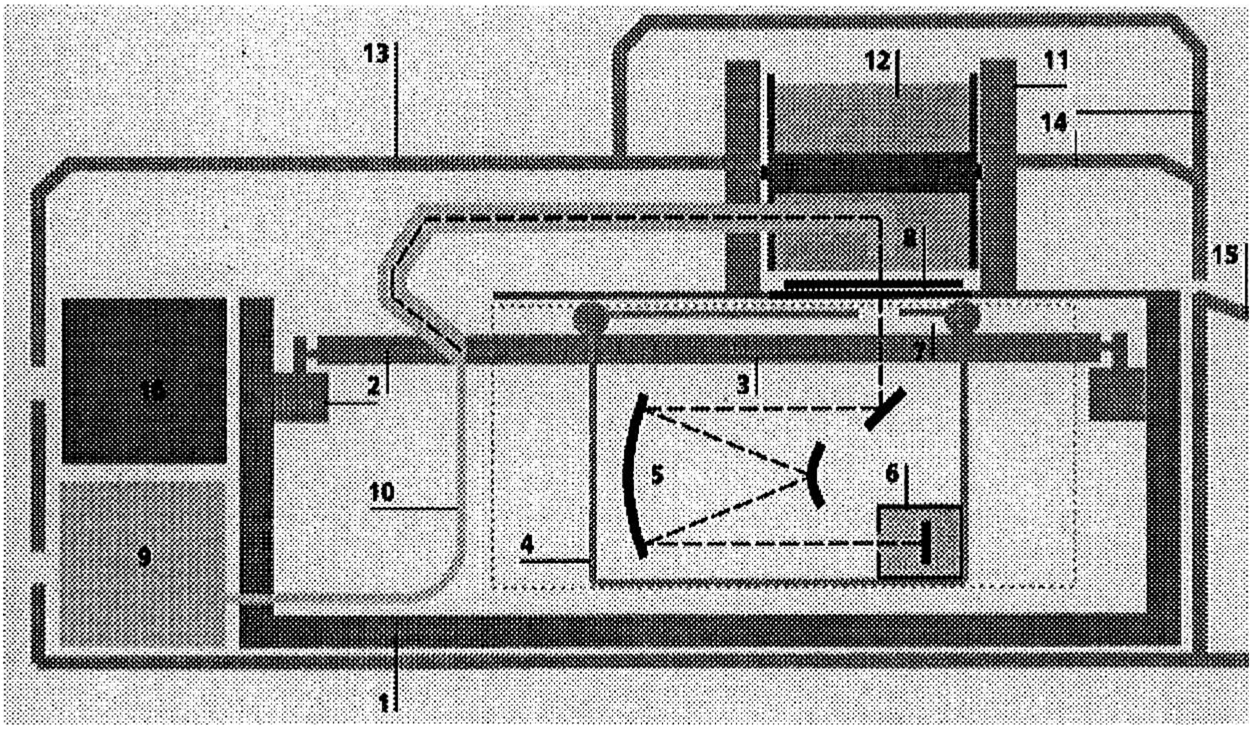

Figure 1: Schematic of SCAI with Autowinder.

All mechanical components are enclosed in a single cast metal base, see figure 1. The core of the mechanical design is the cross slide system consisting of two orthogonal, independently moving carriages. Whereas in the PS1 PhotoScan the image moves on the photo carriage over the CCD-Camera, in SCAI the optical system moves over a fixed image. This carriage is called the *optics carriage*. A combination of rotary and linear encoders report the positions of the carriages to the electronics. The scan area is scanned in a comb-like pattern in several parallel swaths. The swath width is 5632 pixels which, as an integer multiple of the highest geometric resolution of 7 µm, is equivalent to 39.424 mm in the image plane. Thus, SCAI requires only 6 swaths to cover

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one complete aerial image with a width of approximately 230 mm. The exact geometric fitting of adjacent swaths is controlled by a calibration of the system. This calibration can be performed by the user. The object to be scanned, either film or glass plate, is fixed on the photo stage by a glass cover plate. This cover plate can either be lifted manually for loading or unloading film, or its motion can be motorized in conjunction with the optionally-available Autowinder.

2.1.2 Optics module

The optical system from light source to CCD-camera is especially tuned. A thermally insulated lamp module with a stabilized 250 Watts halogen lamp serves as the light source. The light is guided through a flexible fibre optic cable, attached to the optics carriage, towards the glass cover plate. A cross section converter at the end of the round fibre optics evenly distributes the light over a rectangular window covering the area of the CCD-camera. A special glass plate scatters the light and generates diffuse illumination for the film. A prism guides the light path to the mirror lens system. Exiting this system, the light then strikes the three linear arrays of the CCD-camera.
Diffuse illumination has the property that small scratches and dust in and on the base of the film are not imaged in the digital image, see figure 2. Instead, the corresponding portion of the emulsion is contained in the digital image. However, scratches and dust in and on the emulsion are still visible in the digital image. In the optical path there is an infrared filter which cuts off this portion of the power spectrum of the light source. This ensures that only visible red light gets imaged onto the red CCD-array.
The mirror lens system itself possesses two advantages for SCAI. First, it is lightweight, minimizing the weight of the moving carriage. This gives the advantage of simplifying the design of the system required to move it precisely. Secondly, mirror lens systems have the property of zero distortion and are free of chromatic aberrations. This of course has a positive influence on the quality of the digital image.

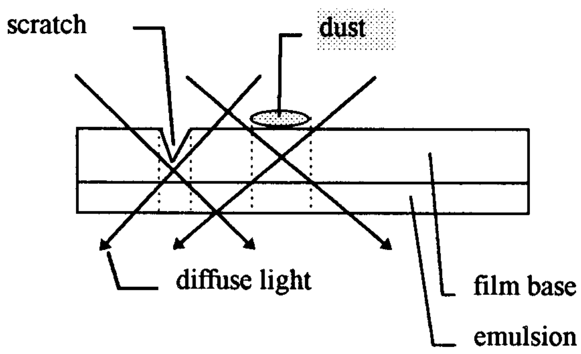

Figure 2: Effect of diffuse illumination.

2.1.3 Electronics module

The electronics module is composed of several components which are placed as funtional units on several boards. These boards are connected via a proprietary bus, specifically designed to fulfill the high data throughput of the three linear arrays of the CCD-camera. This bus also guarantees independence from commercial bus systems which often appear to have a short life time. The most important boards are:

- CCD-board,
- A/D-board,
- M-board and

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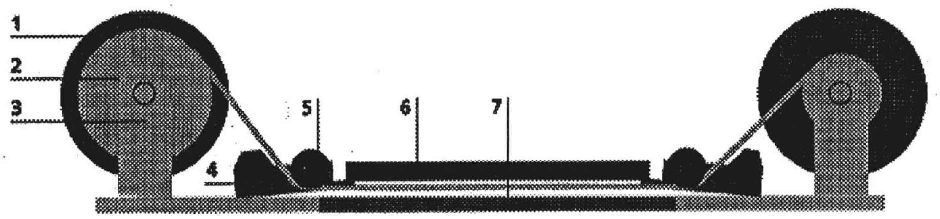
- SCSI2-board.

The circular CCD-board carries the CCD-camera which is placed in the focal plane of the mirror lens system and where it collects the light transmitted through the image being scanned. The circuitry on this board provides the primary control of the CCD-camera. A special loop ensures that the red, green, and blue linear arrays receive the light from identical geometric locations in the film. In order to maintain a constant micro-climate, a fan which constantly blows fresh air around the CCD-camera is placed on this board.
The analog signals of the CCD-camera are converted into digital signals on the A/D-board. For each color channel, an independent conversion takes place. Every single pixel in each of the three linear arrays obtains a linear correction consisting of gain and offset. For this purpose, the conversion uses pre-computed look-up-tables (LUTs) which, for every analog input value, contain a corresponding digital output value. Such LUTs are applied in time-critical environments such as the high speed A/D-conversion on the A/D-board. In order to establish the red, green, and blue LUTs, each linear array is radiometrically calibrated by adjusting every pixel to the dark current of light and the bright current of light. This process of radiometric calibration is called the *normalization*. For each color channel, the A/D-board delivers 8 bit grey values. One color pixel is composed of three channels. The stream of color pixels is transferred via the proprietary bus to the SCSI2-board.
The M-board holds the controlling circuitry for the DC-motors of the cross-slide system. If the Autowinder is attached then the M-board also controls the motors of the film reels as well as the motors for lifting and lowering the glass cover plate.
The SCSI2-board processes the incoming pixel stream and pipelines it to the workstation. In addition to this, commands and status messages are also transferred via this standardized interface. This makes SCAI a regular peripheral device from the point of view of a workstation.

2.2 Autowinder

The Autowinder has two motorized drives and is able to position an arbitrary image in the roll film accurately on the photo stage, see figure 3. In conjunction with the SC-software, this device allows SCAI to operate in the unattended mode and to scan a roll film autonomously.



1 Film reel
2 Film
3 Motorized film drive
4 Motorized lifting device
5 Deflection roller, frame counter
6 Glass cover plate
7 Photo stage

Figure 3: Schematic of the Autowinder.

During the re-winding operation, the roll film is pulled under deflection rollers through the gap between the photo stage and the glass cover plate which is automatically lifted. There are two

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deflection rollers on each side of the photo stage. The glass cover plate is lowered automatically after the film advance operation. The use of narrow deflection rollers at the lower and upper borders of the film instead of a drum roller avoids the pollution or even the damage of the base of the film by such a drum roller. An electronic frame counter allows precise prepositioning of a selected image. The reels can take a roll film of 150 m in length. Loading and unloading of partly wound film is possible. For fast re-winding the roll film can be moved at a speed of 1 m/s.

2.3 SC-Software

The user interface of PHODIS SC is of the same design as other PHODIS-applications. Existing PHODIS users should be therefore able to adapt quickly to this new environment. A context-sensitive on-line help system offers appropriate help in any situation. The general software concept of the PHODIS-applications is described in more detail in Mayr 1995 and not repeated here. The SC-software package is project oriented and stores all information pertaining to the raster images using its project management tools. The operator can, for example, change the roll film at any time then recall all relevant parameters for that roll film when re-loading it again.
In this paper only the most important software functions are briefly mentioned. Probably the most often used function is one for defining a new image to be scanned. It is possible to perform an overview scan, called a *pre-scan* in PHODIS SC, with 224 µm geometric resolution. Usually the pre-scan covers the complete photo stage. The pre-scan is visualized, and the user has the opportunity to digitize the area of interest by dragging a window around it. It is possible to select predefined areas on the photo stage or to select areas with predefined proportions of width and height to fit standard sheet sizes, e.g. DIN A5. Other necessary input parameters are the selection of an image file name, the geometric resolution, the image file format, the color mode, and the illumination time of the CCD-camera. These parameters can either be retained from the values of the previous scan or the operator can set or modify any parameter. It is possible to generate the image file name by using a user definable mask consisting of an alphnumeric string. Also, the user may decide if large color images, e.g. > 200 MB per color channel, are stored either in one single file or in three separate files. This makes the handling of very large images easier.
Geometric resolutions between 7 µm and 224 µm are possible. The scanning process can store the digital images directly in either the Zeiss-TLD format, which is a tesselated image file format, or in the TIF-Format (Tag Image File Format). Other image file formats, e.g. PostScript or SunRaster, are obtained by applying the integrated image raster data converter. One can select between a monochrome scan or color scan. The exposure time determines the mean brightness of the image and can be selected for each image individually. In addition to this, the user may select amongst a variety of predefined LUTs in order to improve the appearance, e.g. brightness or contrast, of the image or to invert it, e.g. to convert from negative to positive. These LUTs are applied during scanning. Prior to the scan all available parameters are checked by the software, and during scanning the progress is visualized through a dynamic percentage bar. Once complete, the scanned image is displayed and the user may accept the result or modify the image using one of the image processing functions supplied.
Besides this core scanner functionality, PHODIS SC includes some photogrammetric functions. It is possible to determine the interior orientation of the digital image. Part of this process is the selection or definition of an aerial camera by calling the PHODIS-camera-editor which is common to all PHODIS-applications. The interior orientation can be done either interactively or in automatic mode. In the interactive mode, SCAI scans image windows around the fiducials and offers these for manual measurement on the display. The automatic interior orientation (AIO) is a postprocessing step which takes as input an already scanned image. AIO automatically searches for, finds, and measures the fiducials (Schickler 1995). The pixel coordinates of the fiducials obtained by either

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measurement method are used in the determination of the transformation parameters between the pixel coordinate system and the image coordinate system. These transformation parameters are stored in the header of the image file. AIO is especially important to SCAI equipped with the Autowinder in order to deliver photogrammetric images automatically. Another example of a photogrammetric function is the automatic generation of an image pyramid. This is used e.g. in the automatic aerotriangulation (Mayr 1995), or in the automatic relative orientation (Tang and Heipke 1994). In this way, important photogrammetric requirements can be resolved on the scanning device itself. The SC-software may also be used with SCAI disabled for the purposes of doing pre-processing or post-processing of images or for doing maintenance work on SCAI during workstation operation hours.
When an Autowinder is attached to SCAI, the unattended scanning mode is possible. In order to kick off this process, the operator prepares a batch job by defining all images which are scheduled to be scanned. One can select either all images on the roll film or an arbitrary sequence of images to be scanned. Each image may be assigned an individual set of scanning parameters as explained above. The automatic image file naming tool is also an important feature for this unattended mode.

3. INTEGRATION IN PHODIS

PHODIS SC is integrated into PHODIS in two senses. First, in common with all other PHODIS-applications, it uses the same computer platform from Silicon Graphics Inc. (SGI), see table 1. It therefore follows that PHODIS SC may be implemented on the same SGI-workstation which already serves for other PHODIS-applications, e.g. PHODIS OP, PHODIS ST. Of course, it is able to run as a standalone application as well. Second, PHODIS SC uses the same digital photogrammetry base as the other applications (Mayr 1995). This guarantees easy data exchange and a homogeneous user interface. As an open system, all PHODIS-applications come with programming libraries and source code examples for access to the Zeiss-TLD image file format as well as to the photogrammetric parameters. The integration of a PHODIS-application into an existing user environment is possible in this way.

PHODIS Product	Photogrammetric Application
PHODIS SC	photogrammetric scanning
PHODIS AT	automatic aerotriangulation
PHODIS ST	digital Stereoplotting
PHODIS TS	automatic DTM-generation
PHODIS OP	digital orthoprojection
PHODIS M	monoplotting

Table 1: PHODIS Products and applications.

4. CONCLUSIONS AND OUTLOOK

The new PHODIS SC scanning system permits the processing of uncut, original roll film. An automatic process converts an entire roll film or selected images into digital images and delivers these to the applications in digital photogrammetry, see table 1. The modular design of the system permits the later extension of SCAI with the Autowinder. In this way SCAI can dynamically fit the requirements of the user. Due to the requirement of automatic roll film scanning, a new instrument design was chosen. In terms of geometric and radiometric resolution and geometric accuracy, SCAI delivers equivalent results to those of the PS1 PhotoScan. The connection of SCAI to the SGI-platform and the use of the PHODIS-specific environment integrate the new scanner system in an efficient way into PHODIS. For example, the same SGI-workstation may have PHODIS AT, PHODIS TS, PHODIS OP, and PHODIS M implemented. Thus, one workstation is available for a variety of applications. In this context one can think of digital photogrammetry as being more universal than analytical photogrammetry.

The amount of data generated by a system like PHODIS SC can be huge. A single monochrome roll film may hold up to 500 images. Scanning all of them with a resolution of 14 µm produces approximately 270 MB per image or 135 GB for the complete roll film. The administration of such an amount of data requires a special archiving system. Technically, jukebox-systems appear to offer a solution. Image compression techniques are available but of these, only non-reversible methods achieve acceptable compression ratios, and their application is still being discussed in the digital photogrammetry community (Jaakkola and Orava 1994). Even image compression methods however cannot exist without archiving procedures. Consequently, the connection between roll-film-capable scanners and archiving systems will gain in importance in the future. With automatic aerotriangulation and digital aerial image archives there are already applications demanding such a solution.

5. REFERENCES

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