# Swissphoto's Automated Digital Photogrammetric Production Environment

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**Abstract**

In recent years digital photogrammetric systems are increasingly used in photogrammetric production to significantly improve the efficiency of the production processes. However, for each specific production the systems require tuning and customisation by additional software developments, specially for automation and handling of large data volumes in big production projects.

In this paper, we present the implementation and establishment of a digital photogrammetric production environment in the private company Swissphoto Vermessung AG, formerly swissair Photo+Surveys Limited. A high efficiency of the production environment was achieved by automation of the data flow, integration of systems from different vendors and optimisation of the work flow through interfaces and hardware. The establishment of the digital production environment was influenced by the requirements of the project *swissphoto*, i.e. the production of digital colour orthophotos over the entire area of Switzerland.

## 1. Introduction

The transition from analytical to digital photogrammetry has been underway in private photogrammetric companies since 1992. One of the major advantages of digital photogrammetry is the potential to automate photogrammetric production processes efficiently, thus substantially improving the price/performance ratio for photogrammetric products and services. Therefore, image processing and computer vision techniques have successfully been employed for facilitating automated and automatic procedures using digital aerial images such as orientation (*Heipke* 1997), point transfer in photogrammetric block triangulation (*Tsingas* 1992), and the generation of Digital Terrain Models (*Krzystek* 1991). But today, the key to an efficient photogrammetric production environment is the combination of the following criteria: (i) the degree of automation in each data production process including self-diagnosis and quality control, (ii) the level of system integration, (iii) and the optimisation of the data and work flow using large data volumes. In order to achieve adequate productivity, extensive refinement, improvements and additional software developments for commercial digital photogrammetric systems are required. Consequently, the user can customise the commercial systems to his own technical specifications.

The customisation of commercial systems can be achieved by the following steps: (i) automation of procedure by batch processing and additional software specially for quality control, (ii) system integration by setting up the optimal hardware and software for each processing step, and (iii) optimisation by tuning the different system components through interfaces and a defined data/work flow.

The implementation of the digital photogrammetric production environment, its tuning and customisation, the current status and its performance are described in this article. This paper also briefly introduces the company Swissphoto, its history, services, and its transition to digital systems.

## 2. The company and its history

Swissphoto Vermessung AG is the largest provider of photogrammetry, engineering surveys and geoinformatic services in Switzerland today. There are more than 75 people employed in the head office in Regensdorf-Watt and in the two Swiss branch offices in Zollikon (Zurich) and Altdorf (Canton Uri). The company was founded in 1931 by W. Mittelholzer, a Swiss flight pioneer, under the name Swissair Photo Ltd. In 1972 the firm merged with Karl Weissmann Vermessungen AG to form Swissair Photo+Surveys Ltd. After 66 years as a 100% subsidiary of the national airline 'swissair' a management buy-out was performed in 1997. Under the new name 'Swissphoto Vermessung AG' the company is active on the national and international geo-data market. For the international market strategic partnerships have been founded. In July 1997, Swissphoto Vermessung AG achieved the ISO-9001 quality certificate for the new developed and implemented quality management system.

Swissphoto Vermessung AG specialises in acquisition, processing, management, analysis and presentation of spatial data. The company combines its more than 60 years of experience in aerial photography and engineering with the

modern digital know-how of a leading supplier of comprehensive geographic services. The result is a wide range of services and products which cover all aspects of spatial information processing. The services of Swissphoto include aerial photography, analytical and digital photogrammetry, digital image processing, scanning and plotting, digital cartography, engineering and cadastral surveying, navigation charting, training and consulting, and geoinformatics. Archive products include aerial photographs from 1917 until today, digital terrain models and orthophotos covering the whole of Switzerland.

### 3. The digital step

In the following some key points for the implementation of digital systems at Swissphoto are summarised:

- increasing demand for digital information, specially for digital orthophotos
- technical progress and innovation by new techniques and systems
- rapid progress in the development of the computer performance
- efficiency to meet the market requirements for fast and high quality data production
- chance for innovation by new type of products and services, and its flexibility

Nevertheless, the major influence for the development of a digital photogrammetric production line was given by the large national orthophoto project *swissphoto*, which had to be realised in a reasonable time period. Consequently, this required a high level of automation in all production processes, e.g. scanning, aerial triangulation, DTM and orthophoto generation, mosaicing, data management, etc., for efficiency, time and cost saving reasons. The orthophoto project *swissphoto* was started in spring 1995 under private initiative, in order to provide up-to-date geo-data covering the entire area of Switzerland (42'000 $km^2$), derived from aerial images. Within three years digital colour orthophotos with a pixel size of 0.75 m at ground scale were produced for the whole country using commercial digital photogrammetric equipment.

The project *swissphoto* is described in *Kersten* and *O'Sullivan* (1996b).

### 4. Current digital photogrammetric systems used

For the production of the *swissphoto* orthophotos, digital photogrammetric equipment was used from LH Systems (UNIX based scanning and stereo stations) and from ISM (NT based orthophoto stations). The continuous progress in upgrading the hardware components of the production systems is described in chapter 5. The current digital photogrammetric production environment of Swissphoto Vermessung AG consists of several workstations using three different operating systems: UNIX, NT and MacIntosh. All workstations are integrated in a fast, wide SCSI ethernet network (100 Mbit).

The major parts of the current digital production environment are summarised in the following (see Fig. 1):

- *UNIX workstations* (one Digital Scanning Workstation DSW300, three Digital Photogrammetric Workstations DPW770, and one administration workstation using SUN Sparc 4 as computer platform)
- *NT workstations* (one Image Server including YAMAHA CD-Writer and 46 GB hard disk, three Digital Orthophoto Workstation DOW, one Backup Server using DLT Quantum 2500 with 5 tapes DLT4000)
- *Mac workstation* (one Digital Image Processing Workstation)

Additionally, two analytical plotters, Leica SD2000 and Kern DSR14 are in use in analytical photogrammetric production.

### 5. Procurements of digital systems (technological update)

Continuous upgrade steps are necessary to meet the requirements for a highly efficient digital production environment. Consequently the latest software releases of the current photogrammetric systems used are implemented to increase the production performance. But in addition, the speed of production is highly influenced by the performance of the computer hardware. Swissphoto have consistently achieved high output within the production environment through continual hardware upgrading as well, as described below.

Swissphoto started the transition from analytical to digital photogrammetric production systems after the ISPRS congress in Washington D.C. in October 1992, when the first producer licence of the software SysImage was purchased from ISM. The hardware used was a PC 486 with 33 MHz frequency and 1 GByte hard disk. At that time, the system was capable of producing only b/w orthophotos. The continuous technological update is summarised in the following:

- *August 1995:* implementation of integrated production systems (one dual station DSW200/DPW770, one stereo station DPW770, both running on SUN Sparc 20) from LH Systems (former Leica/Helava).

- *October 1995:* split up of the dual station to a scanning station DSW200 and to a DPW770.
- *July 1996*: increased scanning production by renting a second DSW200 station until January 1997
- *December 1996*: purchase of the third photogrammetric workstation, a mono-station DPW670 (SUN Ultra 2 with two processors of 170 MHz each and 256 MByte RAM).
- *January 1997*: installation of a digital image processing workstation (Macintosh system UMAX with 200 MHz, 80 MByte RAM, 2 GByte internal disk and 31 GByte external disk) for improvement of the radiometric quality of the digital orthophotos using Live Picture as the image processing software.
- *May 1997*: upgrade of all three SUN Sparc 20 to SUN Ultra 1 (200 MHz/196 MByte RAM).
- *1996/1997*: purchase of the second and third SysImage licence for the NT based orthophoto workstations.
- *February 1998*: upgrade of the network from 10 to 100 MBit per second as a major breakthrough for the UNIX and NT based production environment.
- *February 1998:* installation of a NT image server (2x 350 MHz and 512 MByte RAM) as the interface between the UNIX DPW's and the NT orthophoto workstations.
- *February 1998:* two PC based orthophoto workstations were equipped with two PC's each, where each of the PC uses a dual pentium processor (350 MHz, 256 MByte RAM). One station is equipped with a 24 inch monitor, while the second station has two 21 inch monitors. The operator uses a switch box to manage all processes of the orthophoto workstation on the two PC's.
- *April 1998*: exchange of DSW200 to DSW300.

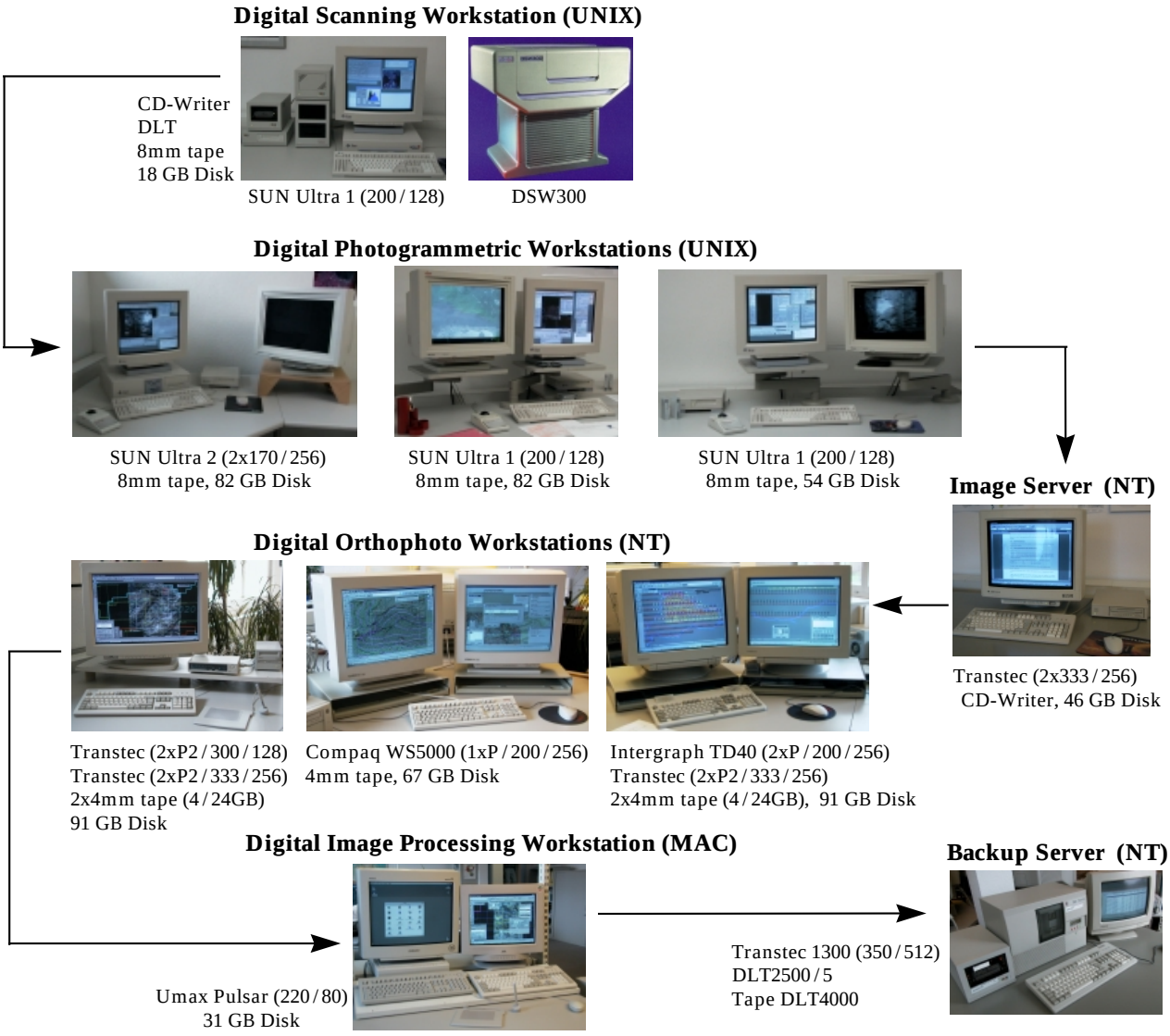


Fig. 1: Swissphoto's digital photogrammetric production environment 1999

- *July 1998*: upgrade of the mono-station DPW670 to a stereo station DPW770.
- *February 1999*: installation of a NT backup computer system (350 MHz and 128 Mbyte RAM) using a Quantum DLT 2500 with five 40 GByte DLT tapes for all NT orthophoto workstations.

During the whole phase of upgrading the hardware systems additional hard disk were purchased when needed. At present, a disk capacity of 562 GByte is in use.

## 6. Refinement of the systems (automation, integration and optimisation)

### 6.1. Scanning

From August 1995, images were scanned on a Digital Scanning Workstation DSW200 of LH Systems with a pixel size of 12.5/25.0 micron (b/w or RGB). For high quality scanning the scanner (XY stage) was installed in a separate room, containing air-conditioner, air-humidifier and a dust filter, to minimise dust and dirt on the photos and on the glass plate of the scanner. Since April 1998, the new scanner DSW300 is in use. The geometric and radiometric performance of both scanners, DSW200 and DSW300, was evaluated in several tests (*Baltsavias* et al. 1997; *Baltsavias* et al. 1998). Using the latest software release SCAN 4.1 (March 1999) the system is capable of performing re-sampling of the images on-the-fly during scanning. In general, quality control of the scanning is guaranteed by periodic radiometric and geometric calibration of the scanner. For each specific scanning project, the quality of the scanned images is guaranteed by visually checking of each minified image on the screen. All scanned images are transferred to internal workstations on-line, but can be delivered on Exabyte tapes (4 and 8 mm), on DLT or on CD-ROM depending on the image file size.

### 6.2. Aerial triangulation (AT)

Depending on the project size and the final products, AT will be performed on the analytical plotter or on the digital photogrammetric stations. In an automated production, the digital aerial triangulation (AT) is divided into several processing steps, which include data preparation (photos and control points), automatic data import and image minification, automatic interior orientation, automatic AT measurements, (GPS supported) bundle block adjustment, and quality control. Due to inadequate automation and quality control at the time for the processing of large data volumes using the commercial Helava system, some additional software for batch processing and easy-to-use graphical user interfaces (GUIs) were developed by Swissphoto Vermessung AG. Thus, the use of the highly automated AT processing modules could be facilitated for the operator. The digital aerial triangulation for the project *swissphoto*, its data flow and results, and the additional software modules used are described in the following papers: *Kersten, Th., O'Sullivan, W.* 1996a, 1996c; *Kersten, Th., Haering, S.* 1997b; and *Kersten, Th., Haering, S., O'Sullivan, W.* 1998.

In the following the AT processing steps are briefly introduced:

- *Data preparation*: configuration of photo blocks (providing images, loading digital images from tape, if not available on disk), providing control point data (co-ordinates, overview plot, available sketches).
- *Automatic data import and image minification*: image import into DPW770 and minification of images (building-up image pyramid levels for display and zooming) in batch mode (see Fig. 2), input of GPS photo centre co-ordinates of

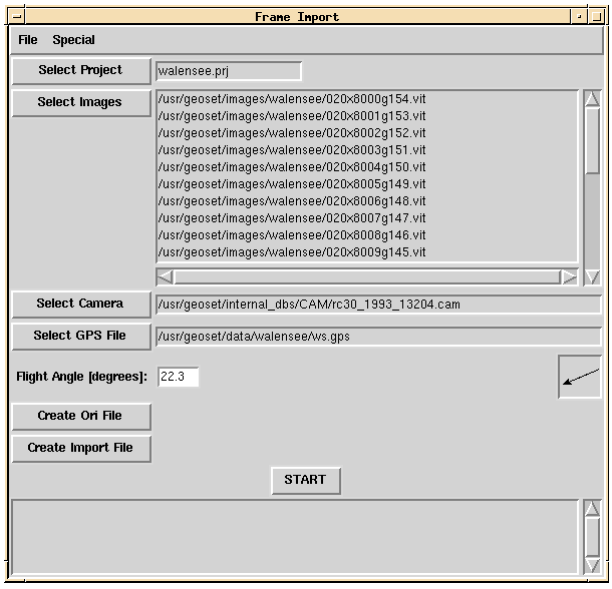


Fig. 2: Graphical user interface for batch frame import

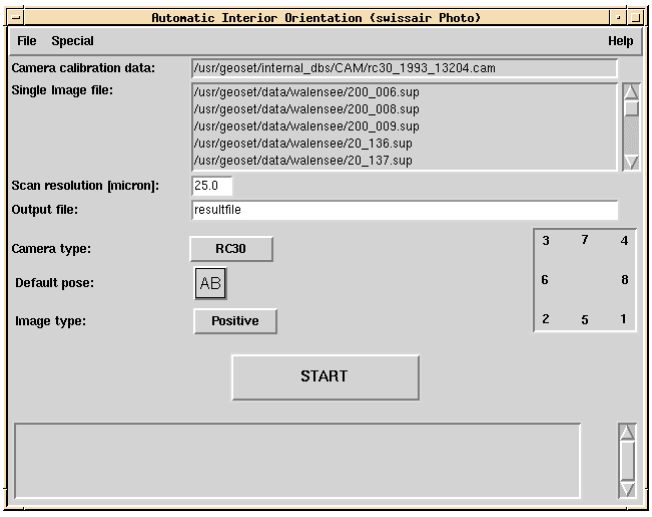


Fig. 3: GUI for automatic interior orientation

each image, preparation of the triangulation file (set-up of AT parameters) in batch mode.

- *Automatic interior orientation:* fully operational automatic interior orientation (IO) of digital aerial images as integrated module of SOCET Set on the DPW670/770 (see Fig. 3) developed by Swissphoto Vermessung AG (batch mode without operator intervention, see *Kersten* and *Haering* 1997a).
- *Automated AT measurements:* Automatic Point Measurement (APM) using a very dense tie point pattern consisting of 98 points as a standard pattern, Interactive Point Measurement (IPM) only of ground control points and additional points in a semi-automatic mode, and Simultaneous Solve (including re-measurements).
- *Threshold blunder elimination (necessary):* Automatic blunder elimination of observations with residuals over a user specified threshold using results of a bundle block adjustment.
- *(GPS supported) bundle block adjustment:* file export in PATB-format, data transfer from DPW to PC, bundle block adjustment with self-calibration using BLUH (bundle block adjustment program of the University of Hannover).
- *Update of orientation data:* interface between BLUH and SOCET SET resp. ORIMA for updating orientation data at the digital photogrammetric stations resp. analytical plotters
- *Quality control:* software module for fast and easy-to-use visualisation of point distribution and photo connections within and across strips, developed by Swissphoto (Fig. 4).

### 6.3. DTM generation

For orthophoto production the digital terrain models are generated at the digital photogrammetric station DPW770 by digital image correlation using the software module SOCET SET ATE (Automatic Terrain Extraction). The following processing steps are used:

- *Set-up:* definition of the used images, correlation strategy (adaptive or non-adaptive), grid space and other parameters, generation of a MSL-file.
- *DTM generation:* batch processing using a Swissphoto GUI
- *Quality control:* (i) rough quality control by generation of a shaded relief and its visual inspection, (ii) fine quality control by visual 3-D inspection and editing of the contour lines in each available image stereo model of the defined project area.

For DTM editing, a fast and easy-to-use GUI for loading of the images (stereo image pairs) on the extraction or console monitor was developed by Swissphoto.

### 6.4. Stereo plotting

Currently, stereo plotting is performed at the analytical plotters for map revision in 2-D (e.g. 1: 10'000 maps of the Swiss Cantons), for official mapping of the cadastre in 2/3-D (1: 500/1: 1000), and for vector data collection in special projects.

### 6.5. Orthophoto generation and mosaicing

The orthophotos are generated image by image at the DPW770 by batch processing. The relevant parameters are set in

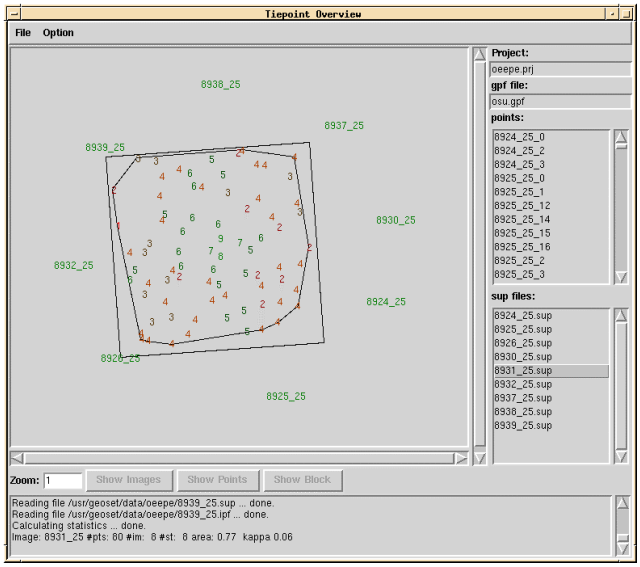


Fig. 4: Graphical user interface for AT quality control

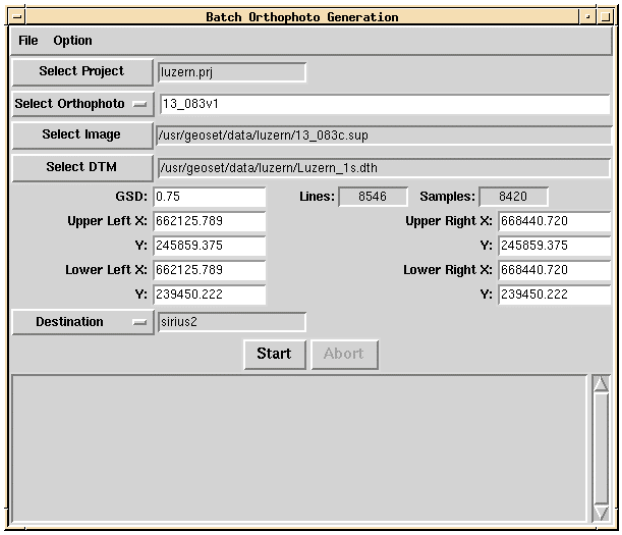


Fig. 5: GUI for batch orthophoto generation

a Swissphoto GUI (see Fig. 5). For the project *swissphoto* the pixel size of the colour orthophotos was 0.75 m, while for large scale projects the orthophotos were generated with a pixel size of 10-25 cm. For mosaicing all orthophotos generated at the DPW's were transferred via the network to the image server of the NT based digital orthophoto workstations (DOW), which use SysImage from ISM for mosaicing and data export. The advantage of SysImage compared to the SOCET SET software of the DPW770 is the fast visualisation of large data volumes on the monitor for semi-automated mosaicing and on-line quality control. Further processing steps are the following:

- Distribution of orthophotos from the image server to the NT workstations
- Conversion of orthophotos from VITEC to SysImage format in batch
- Mosaicing of orthophotos by manual seamline generation and manual colour balancing using brightness, contrast and gamma correction for each single orthophoto
- Generation of huge block files (< 2 GB) containing multiple orthophotos by automatic seamline feathering
- Saving of the block files in SysImage format

### 6.6. Data management and export

Finally, the orthophotos are saved as mosaic blocks with a maximum file size of 1.9 GB (NT system limitations) or with a maximum number of 37 orthophotos (SysImage limitations). These block files are saved on DAT tapes or on DLT tapes on the backup server. For specific projects or customer requirements, the final orthophoto data is usually exported in the following tile sizes (sheets) using TIFF format:

- 3 km x 3 km with a pixel size of 0.75 m (project *swissphoto*)
- 4375 m x 3000 m with a pixel size of 0.625 m (project *swissphoto*)
- 500 m x 500 m or 1000 m x 1000 m for large scale projects with a pixel size of 10-25 cm

For the orthophoto export, the relevant block files are virtually mosaiced with SysImage and the export of regular tiles is performed by batch processing using a DGN file with the pre-defined tiles and special software which was developed by Swissphoto.

The DTM of the project *swissphoto* is saved in 15 km x 15 km tiles on the disks of the DPW's and on Exabyte tapes (8mm).

### 6.7. Image processing

The orthophotos can be delivered in three different quality standards: (i) raw data from SysImage, (ii) GIS quality for data processing on the monitor by image processing with Photoshop or Live Picture, or (iii) high quality for printing of maps by further image processing. The image processing can be performed with Photoshop on the NT workstation or with Live Picture on the MacIntosh workstation. Using Photoshop image processing with a maximum file size of up to 500 MB only can be performed, while with Live Picture image processing with a file size of up to 1.9 GB is possible.

## 7. Performance of the production environment

The following performance of the digital production environment is nominally estimated from results of the project *swissphoto*:

| Process | Scanning | Digital AT | DTM/Edit | DOP | Mosaic | Export |
|---|---|---|---|---|---|---|
| Photos/hour | 6 | 6 | 0.5 | 4 | 4 | 10 |
| Photos/day/shift | 50 | 50 | 4 | 35 | 35 | 80 |

Tab. 1: Estimated performance of the digital production environment

In general, the performance depends on both the photo scale and final pixel size of the orthophotos.

Using the above described production environment, the orthophoto project *swissphoto* was realised within three years. Currently, Swissphoto produces a digital surface model of Switzerland with a grid size of 10 m by digital image correlation on the DPW770 using the photos of the project swissphoto (1995/1996). Simultaneously, digital colour orthophotos of the Canton Jura (840 $km^2$) with a pixel size of 25 cm are generated on the DOW using SysImage.

## 8. Conclusions and outlook

Digital photogrammetric systems have been successfully implemented at Swissphoto in recent years. These systems complement the analytical production line consisting of two analytical stereo plotters. Today, a modern and up-to-date digital photogrammetric production environment is in use at Swissphoto Vermessung AG, which utilises the latest technology and software releases, and highly skilled and motivated staff. Concepts for the implementation of such digital systems are driven by economic requirements of large projects for data production. The pressure of time and costs for the management of these projects requires software and hardware implementation and training-on-the-job. The increase of the production rate through automation, integration and optimisation of the Swissphoto photogrammetric production environment compared with analytical methods cannot be quantified in percentage, but we believe the following aspects, among others, summarise the general improvement:

- implementation of user friendly and easy-to-use graphical user interfaces
- reduction of operators intervention (and errors) through batch processing
- expansion of the production time by batch processing overnight and during weekends
- invaluable software tools and skilled operators for large project processing
- guarantee for higher quality control capability as an integral part of the production
- competitive within a high cost environment.

However, the transition phase from analytical to digital technology is still ongoing. With due respect of the dramatic progress to date, digital photogrammetric systems are still at an early stage of development, with great potential for improvements and further developments. Gruen (1999) foresees possibilities for short-term improvements, and actions, that would require more time to obtain adequate results:

*Short-term improvements*

- Simplification of user-interfaces/better on-line help
- Design of parameter „macros“
- Robustification of key functions
- Inclusion of self-diagnosis
- Provision of quality measures for all results
- Simplification and more flexibility with data import and export.

*Middle- and long-term improvements*

- Implementation of on-line triangulation
- Simultaneous processing of n images (n>2)
- Integration of automated image interpretation (use colour, texture, etc.)
- Usage of a priori knowledge, i.e. existing data (GIS, DTM, etc.)
- Establishment of more advanced post-processing and editing tools
- Implementation of semi-automated algorithms for object extraction
- GIS integration.

Nevertheless, a future vision could be a fully automatic digital photogrammetric system, which performs aerial triangulation (including scanning of photographs if digital images are not available, import of digital image data, interior orientation, point transfer through large blocks, measurements of control points, bundle block adjustment), and generation of digital terrain models and orthophotos including mosaicing and data export. One must be aware that the more automation the systems provides, the more automatic quality control must be also implemented between all processing steps - a control which today is carried out mostly by the operator - in order to guarantee accurate and reliable results.

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