Automatic Tie Point Extraction using the OEEPE/ISPRS Test Data - The Swissphoto Investigations

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ABSTRACT

In this report we present the investigations and results from Swissphoto Vermessung AG for the OEEPE/ISPRS test on performance of tie point extraction in automatic aerial triangulation. For this test all six test data sets which were delivered by the pilot centre were processed on a digital photogrammetric workstation DPW670 (Mono-station) of LH Systems using the software package HATS (Helava Automated Triangulation System) of SOCET SET (Softcopy Exploitation Tools).

1. INTRODUCTION AND MOTIVATION

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. Today, the efficiency of a photogrammetric production environment is mainly based on the degree of automation in data production processes.

Aerotriangulation is one of the key processes in digital photogrammetric production which has still the highest potential for more automation and efficiency. Image processing and computer vision techniques have successfully been employed for facilitating automated procedures in digital aerial block triangulation such as interior orientation (Schickler, 1995; Lue, 1995; Kersten and Haering, 1997), relative orientation (Schenk et al., 1990), and point transfer in photogrammetric block triangulation (Tsingas, 1992). But, aerotriangulation including image import, generation of image pyramids, interior orientation, point transfer, control point measurement, bundle block adjustment and quality control, is one of the most complex processes in digital photogrammetry. The highest potential for efficiency in digital aerial triangulation is based on automatic, accurate and reliable tie point extraction, in order to reduce the intervention of operators. The performance of automatic tie point extraction in automatic aerial triangulation with respect to accuracy and reliability is the major topic of the OEEPE/ISPRS test.

Investigations in automatic digital aerotriangulation have been performed in scientific institutions like Ohio State University (Agouris and Schenk, 1996; Toth and Krupnik, 1996) and University of Stuttgart (Tsingas, 1992; Ackermann and Tsingas, 1994), by system providers like Leica/Helava (DeVenecia et al., 1996) and Zeiss (Braun et al., 1996), and by software providers like Inpho company, Stuttgart (Krzystek et al., 1996). But few users (Kersten and Stallmann, 1995; Beckschaefer, 1996; Kersten and O'Sullivan, 1996, Kersten and Haering, 1997) have reported their experiences in digital aerotriangulation using a commercial photogrammetric system although many systems are already in use world-wide.

The motivation for the participation of Swissphoto Vermessung AG, former swissair Photo+Surveys Ltd., in the OEEPE/ISPRS test is summarised below:

(1) to test images with different scene content and topography for automatic tie point extraction
(2) to test and demonstrate the performance of the system used at Swissphoto Vermessung AG
(3) to compare the results of different systems and different users using the same data sets
(4) to discuss the results of this test with other participants
(5) to see limitations of automatic tie point extraction
(6) to improve our own production environment from the conclusions of the OEEPE/ISPRS test

2. OEEPE TEST DATA

Four small blocks with a maximum block size of 3x3 images and two strips containing both three images have been selected by the pilot centre as test data sets. The selected test data represent various scene content and topography, photo scale variation from 1: 3'000 up to 1: 15'000, different cameras, different overlap configurations, and different film material. The technical description of the delivered test data is summarised in Table 1. Furthermore, the test data sets are scanned on different scanners. The pixel size used varies between 20 and 30 micron, which represent pixel sizes used for triangulation today.

	Echallens	**Kapellen**	**Montserrat**	**OSU**	**München**	**Nevada**
Scene content	open, partly forest	settlement, partly open	forest, partly built-up	built-up, partly trees	city centre	sand desert + vegetation
Scene topography	flat	flat	hilly	flat, buildings	buildings	hilly
Photo scale	1: 5’000	1: 4’000	1: 15’000	1: 4’000	1: 3’000	1: 8’000
Camera	Wild RC10	Zeiss RMKA	Zeiss RMKTOP	Wild RC10	Zeiss RMKA	Fairchild
c [mm]	150	150	150	150	300	150
Film material	B/W	B/W	B/W	False color IR	Color	B/W
Flight date	Sep. 1982	Apr. 1992	May 1995	Sep. 1995	May 1975	Oct. 1981
# of images	3x3	2x3	3x3	3x3	3	3
Overlap f/s [%]	60/30	60/60	60/30	60/60	60	55

Table 1: Technical data of the OEEPE/ISPRS test data sets

The technical information of the scanning of the OEEPE/ISPRS test data sets are summarised in Table 2. The characteristics of each delivered test data set are described in the description of the OEEPE/ISPRS test (Heipke, Eder, 1996).

	Echallens	**Kapellen**	**Montserrat**	**OSU**	**München**	**Nevada**
Scanner	Leica DSW200	Wehrli RM1	Zeiss PS1	Leica DSW200	Zeiss PS1	Zeiss PS1
Pixel size [µm]	20	24	30	25	30	30
Scanned material	negative	negative	negative	positive	positive	positive
Scanned channel	panchromatic	panchromatic	panchromatic	red	red	panchromatic
Scan datum	Jan. 1996	Jun. 1996	Nov. 1996	Oct. 1995	Dec. 1996	Dec. 1996

Table 2: Technical information of the scanning of the OEEPE/ISPRS test data

3. PHOTOGRAMMETRIC SYSTEM USED

3.1. Hardware

The investigations for the OEEPE/ISPRS test were performed on a Helava/Leica digital photogrammetric workstation DPW670 (Mono-station). As computer platform a SUN Ultra 2 (167 MHz) was used with 256 MByte RAM. The OEEPE/ISPRS test data was stored on local disks with an available disc storage capacity of 105 GByte in total. The DPW670 and the hardware periphery used is illustrated in Figure 1.

3.2. Software

For the automatic tie point extraction using the six OEEPE/ISPRS test blocks HATS (Helava Automated Triangulation System) of SOCET SET software (Softcopy Exploitation Tools) was used. The used software release was 3.2.1.2. HATS is a module of SOCET SET for performing block triangulation of suitably overlapping images. The tedious process of selecting and measuring image coordinates of control and tie points is highly automated, with the possibility of operator override. The system flags unacceptable tie points and displays the required images for measurement without operator intervention. All the operator has to do is to re-measure these unacceptable points by moving the floating mark to their proper locations, if requested. The workflow in HATS is defined as follows: Block Set-up, Automatic Point Measurements (APM), Interactive Point Measurements (IPM), Blunder Detection, and Simultaneous Solve (incl. re-measurements of points with large residuals).

Figure 1: Digital aerial triangulation station at Swissphoto Vermessung AG

3. AUTOMATIC TIE POINT EXTRACTION - DATA PROCESSING

The workflow for automatic tie point extraction was divided into the following data processing steps:

- data preparation (loading of data, block configuration, definitions, parameters, etc.)
- automatic data import and image minification
- automatic interior orientation
- automatic AT measurements
- bundle block adjustment
- blunder detection and elimination
- quality control

To facilitate the data processing some additional software for batch processing and easy-to-use graphical user interfaces (GUIs), which were developed by Swissphoto Vermessung AG, were used for these investigations.

3.1. Data preparation for the AAT run

The data preparation included the loading of the digital images from tape and the configuration of the photo blocks by using some of the given information (end and side overlap, average terrain height, approximate flight height above ground). The preparation of the triangulation file, which contains all parameters for the block configuration and for the automatic point measurements, can be performed automatically. The following given information were **not** used: average image scale, type of terrain, initial values for projections centres, azimuth of flight direction, initial values of image rotations and object co-ordinates of any ground control points.

As a preliminary quality control before the measurements the operator checked the overlap of all photos in each block in strip and across strip direction sequentially by visualisation of two overlapping photos in split screen mode on the monitor simultaneously. If the overlap of the current displayed photos was not sufficient defined, the side and end overlap was slightly changed. Finally, if the measuring marks (cursors) were at the same position in the displayed stereo pair, the overlap was well defined, which provides good initial values of the orientation parameters for the automatic tie point extraction.

Before running the automatic tie point extraction a tie point pattern was selected and edited to obtain a well distributed point configuration in each image for connecting the block. A very dense tie point pattern (see Fig. 2) consisting of 98 points (maximum) was used as a standard pattern for all test blocks.

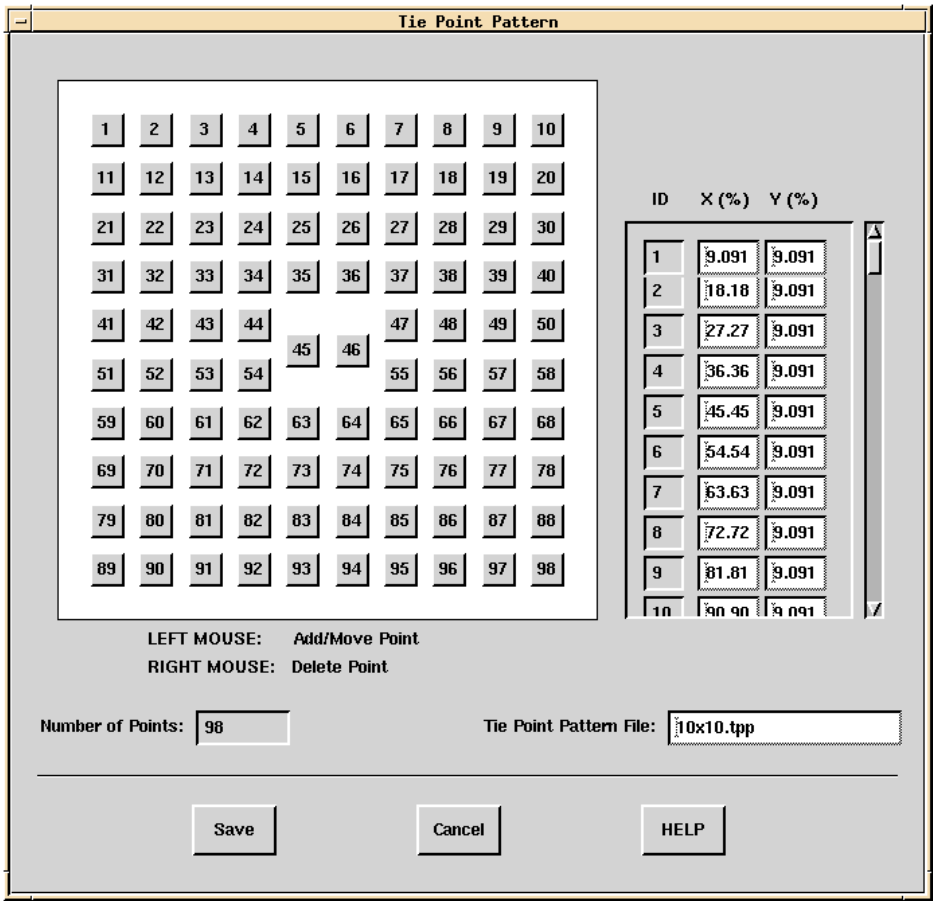

Figure 2: Tie point pattern used for automatic tie point extraction in the OEEPE/ISPRS test data

3.2. Automatic data import and generation of image pyramids

Before starting the measurements, the image import into the photogrammetric station and the minification of the images (building-up image pyramid levels for the correlation algorithm and for display/zooming) is performed fully automatically in a batch mode, which takes between 30 and 40 seconds per image on the SUN Ultra 2. Given station co-ordinates or GPS photo centre co-ordinates of each image could also be automatically imported in batch mode to provide approximate values for the overlaps between images in the blocks.

3.3. Automatic interior orientation

The interior orientation (IO) of each image can be determined semi-automatically or fully automatically. Due to the small number of images the semi-automatic mode was performed in these investigations to check the quality of the fiducial marks. In the semi-automatic mode the operator positions the cursor at the first two fiducial marks approximately so that the correlation algorithm can perform the precise measurements of the fiducial marks. The rest of the four or eight fiducials are measured fully automatically using approximations computed from the information of the first two measurements. Using this mode it took approximately 30 seconds manual operator intervention per image.

To avoid the time consuming determination of the interior orientation by the operator, a fully operational automatic interior orientation (auto_io) of digital aerial images was developed at Swissphoto Vermessung AG and integrated into SOCET SET which can be performed in batch mode without operator intervention. The IO of an unlimited number of images related to one given camera type can be automatically determined in one step including a quality control. The speed of the measurements and IO determination is approximately 5 seconds per image. The algorithm for the automatic interior orientation is described in Kersten and Haering (1997). The automatic mode was only used for the block Echallens. The results (sigma σ of affine transformation) of the interior orientation for each block are summarised in Table 3. Due to the well defined synthetic signals of the fiducial marks a result of better than one third of the pixel is achievable for the correlation algorithm. According to the average sigma σ of the six tests blocks, the results of the interior orientation can be grouped into three classes: very good (Echallens, München), good (Kapellen, Montserrat) and bad (OSU, Nevada). For block Nevada the obtained result can be addressed to the bad definition of the fiducial marks, while for block OSU the sigma 0 indicates the bad geometric quality of the scanned images. A visual quality control shows a pattern of the scanned patches in the OSU images, which is typical for the DSW200 scanner, if the geometric and radiometric calibration is not precise. If the geometric or radiometric quality of the scanned OSU images is bad, this may influence the precision of the automatic point transfer.

	Echallens	**Kapellen**	**Montserrat**	**OSU**	**München**	**Nevada**
# of fiducial marks	4	4	8	4	4	4
Measurement mode	auto	semi-auto	semi-auto	semi-auto	semi-auto	manual
Pixel size [µm]	20	24	30	25	30	30
Max. sigma [µm]	8.7	9.7	8.3	20.2	5.5	18.2
Min. sigma [µm]	1.7	4.7	6.6	6.5	1.4	7.4
Average sigma 0 [µm]	4.4	7.7	7.2	13.6	3.7	14.0

Table 3: Sigma 0 of affine transformation for interior orientation [µm]

3.4. Automatic tie point extraction

After data preparation and interior orientation the automatic tie point extraction as APM was performed as a batch process using a dense tie point pattern consisting of 98 points per image. The entire tie point measurement process is automatic. The matching algorithm is hierarchical and area-based. The used parameters for the automatic point measurements are defined in two strategy files. In the first file the general parameters for the correlation algorithm are defined, while in the second file the parameters for the correlation in each pyramid level are set. Although algorithm parameters could be changed by the user in the strategy files, no detailed description is available. Even if a description would be available, a certain expertise about matching is necessary. On the other hand an adaptive approach for matching would increase automation and reduce time consuming fine tuning for each block. The strategy files used are the same for all test data sets. A detailed description of the matching strategy in HATS is given by Paderes et al. (1998).

	Echallens	**Kapellen**	**Montserrat**	**OSU**	**München**	**Nevada**
Pixel size [µm]	20	24	30	25	30	30
# of images	9	6	9	9	3	3
Success. meas. pts [%]	88	75	73	65	84	40
# of measured points	699	436	690	820	234	146
# of blunders	35	59	63	209	19	2
Blunders [%]	5.01	13.53	9.13	25.49	8.12	1.37
# of remaining points	664	377	627	611	215	144
Sigma 0 [µm]	2.6	5.5	4.5	7.3	4.8	5.1

Table 4: Results of the automatic tie point extraction using OEEPE/ISPRS test data sets

On the SUN Ultra 2 APM took between 3 and 7 minutes per image (see also Table 5). After APM is finished HATS expresses the quality of the point transfer as a rate of successfully measured points. For the six test blocks the success rate can be grouped into three classes: more than 80% of successfully measured points is good (Echallens, München), more than 70% is acceptable (Kapellen, Montserrat), and less than 70% is bad (OSU, Nevada). Due to the low contrast in the images (sand dunes) the result for the point transfer rate of block Nevada is not surprising. On the other hand, due to the overlap of 55% in the three Nevada images the system does not measure many 3 fold points.

But again, the results of block OSU are not good, which can be also attributed to the bad quality of the digital images. The results of APM for all test blocks are summarised in Table 4.

3.5. Block adjustment, blunder detection and elimination

After the automatic point measurement an adjustment was performed using the module „Simultaneous solve“ of HATS. The measured image co-ordinates were not corrected by the influence of earth curvature and refraction. In the adjustment no self-calibration was used for compensation of systematic errors by additional parameters. As a result of the adjustment the residuals of the image point measurements were listed on the monitor.

Instead of re-measuring all points with errors a blunder detection routine eliminates automatically all observations with residuals over a user specified threshold. Simultaneous solve and blunder detection were performed in an iterative mode until the data set was free of obvious blunder. This blunder detection used only a threshold criterion, which was defined by the operator after analysing the residuals. This procedure assumes high redundancy in the observations.

The results of the final adjustment and of the blunder elimination are summarised in Table 4.

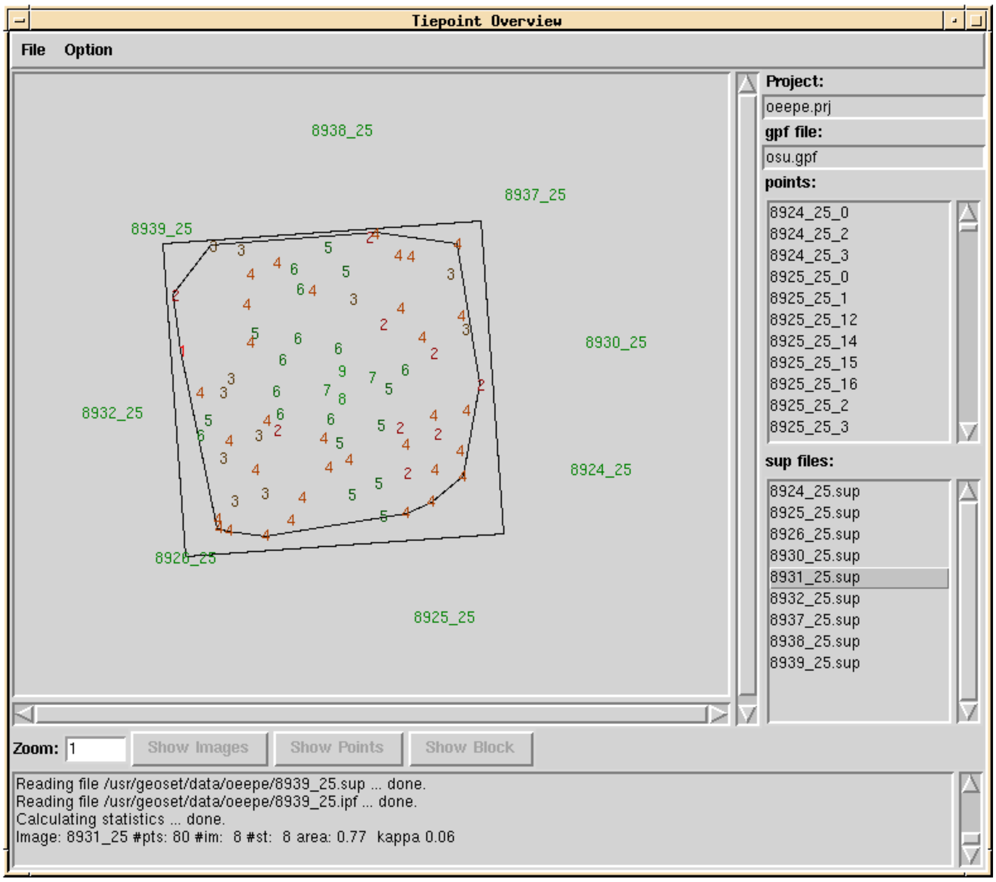

Figure 3: Visualisation of photo connections within a triangulation block for quality control

3.6. Quality control

The geometric quality control for the block is given by the results of the bundle adjustment (σ_0, RMS, etc.). Furthermore, due to the high automation of the measurements and gross error elimination it is essential to check the photo connections within each strip and across the strips, in order to confirm a reliable point distribution and connection in the triangulation block. Therefore an additional software module was developed by Swissphoto, which provides a fast and easy-to-use visualisation of all point connections in the block (Fig. 3). Using this module the operator is able to scan quickly through the block, photo by photo, strip by strip to check visually the number of rays per point, the distribution of points in each photo, and, by clicking on the photo number in the display window, the connections of each photo (see Fig. 3).

4. TIME REQUIRED

The time required for the automatic tie point extraction of each test block using a customised approach of HATS is summarised in Table 5. In this table all elapsed times of both the operator and the computer are summarised related to each processing step in the workflow (preparation, interior orientation, image pyramid, ATPE, blunder elimination). For all test blocks between 11 and 14 minutes per image were used except for block Montserrat. For this block the blunder elimination took four times longer than for the other blocks due to convergence problems of the block adjustment.

Processing steps	**Echallens**	**Kapellen**	**Montserrat**	**OSU**	**München**	**Nevada**
Interior Orientation	4.5	3.0	4.5	4.5	1.5	3.0
Image pyramid	6.0	2.7	3.0	3.8	1.0	3.0
Preparation ATPE	30.0	20.0	30.0	30.0	15.0	10.0
ATPE	40.0	36.0	53.0	60.0	8.0	8.0
Blunder elimination	15.0	15.0	60.0	15.0	15.0	10.0
Total elapsed time	95.5	76.7	148.5	113.3	40.5	34.0
Elapsed time per image	10.6	12.8	16.5	12.6	13.5	11.3

Table 5: Elapsed time for the processing steps of ATPE (**A**utomatic **T**ie **P**oint **E**xtraction) [min]

5. ALGORITHMIC ASPECTS

The quality of the automatic point transfer resp. the correlation algorithm are dependent on the image quality (including scanning and weather conditions) and terrain characteristics (e.g. texture and height differences). In summary, the following aspects cause problems for the correlation algorithm:

- Extreme height differences in the images resp. block
- Strips with different flight dates (vegetation changes in summer)
- Shadows from early morning flights (bad quality terrain representation)
- Densely forested areas and lakes, occlusions by buildings in urban areas
- Triangulation blocks with variation of the photo scale within the block (from strip to strip)
- Bad radiometric or geometric performance of the scanner

To improve HATS with respect to reliability, speed, precision, robustness, flexibility, and user-friendliness the following improvements should be implemented:
(1) The use of an existing DTM in APM could speed up the APM process and increases the precision and robustness significantly, especially in mountainous and alpine regions, so that the rate of successfully measured points can also be increased.
(2) The use of an adaptive matching strategy using feature-based matching for rough measurements and area-based matching for precise measurements including automatic adaptive tuning of the matching parameters.
(3) The use of GPS data, additional parameters and an efficient band ordering algorithm for the re-linearisation of the normal equation system in simultaneous solve would lead to more flexibility and speed-up of the adjustment module in HATS.
(4) The use of on-line triangulation algorithms (sequential estimation in bundle block adjustment and data snooping in blunder detection) during APM can increase the quality of the automatic measurements through elimination of gross errors during the data capture phase (Gruen, 1985a).

6. CONCLUSIONS AND OUTLOOK

It could be demonstrated that the DPW670 (SOCET SET) of LH Systems using HATS is capable of performing automatic tie point extraction using digital images with different types of scene content and topography. The digital automatic point transfer was performed successfully for the delivered six test blocks with an precision of better than 1/3 of the pixel size and an elapsed time of about 12 minutes per image. Although the results of these test blocks obtained at Swissphoto are very good, there is still potential for improvements concerning automation in digital point transfer. In our opinion the used test blocks could not demonstrate the limitations of automatic tie point extraction using current available commercial triangulation software packages. For further investigations the following aspects could be take in account:

- Larger blocks (> 100 images)
- Smaller photo scale (> 1: 20'000)
- Blocks representing more difficult terrain types (mountainous or alpine regions)
- Difficult block configurations (no regular blocks)
- Blocks with varying photo scales within the block
- Colour images

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