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Higher performance with automated arial triangulation

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ABSTRACT

Automatic measuring procedures have been available for the aerial triangulation for some time now. The question whether this procedure is suitable for the employment in day to day practice within an consultancy office and whether an increase of efficiency within the aerial triangulation can be achieved is being researched.

1. INTRODUCTION

The aerial triangulation within the photogrammetry is an important technical procedure for the computation of the exterior orientation of images and serves as a basis for an exact geometrical evaluation. The practical work within the consultancy office having specialised in photogrammetrical survey can no longer be imaginable without the aerial triangulation.
Therefore Aerowest Photogrammetrie H. Benfer GmbH (AWP) orients every year several thousand images through aerial triangulation. Until now it was standard practice to use the analytical measurement of aerial triangulation, this year the digital-automatic aerial triangulation was introduced. Lastly the move to digital photogrammetry is due to the generally expected increase of efficiency through this form of measurement procedure. The following illustrates the experience with the new technique during the first practical applications.

2. PROCEDURES OF AERO TRIGONOMETRICAL SURVEY

The individual methods of aerial triangulation may be distinguished through the different types of measuring procedures. Traditionally widely used is the analytical measurement by an operator. Digital procedures do not use analogue film frames when measuring but a digital or digitized image (film). So digital measurement of tie points either can carried out by an operator, half automatically or automatically (Schenk, 1995). Clarification can be gained from the flow chart referring to the analytical and digital-automatic aerial triangulation (Table 1).

	Analytical aerial triangulation	digital-automatic aerial triangulation
Supply of the documents	op	op
Interior orientation	op	a
Relative orientation	op	-
Tie point measurement	op	a
Control point measurement	op	op
Adjustment	op	op
op = by operator	a= automatic	

Table 1: Flow chart aerial triangulation.

The two procedures differ fundamentally only in the measurement. When working analytically the operator measures sequentially one model after the other.
On carrying out a digital-automatic measurement the individual steps (digitizing, interior orientation, measurement of tie points and control points) are carried out one after the other but in each case for a great number of images at the same time.
The digital automatic measurement for aerial triangulation starts with the scanning of the images. Nowadays, depending on the type of the scanner this procedure is almost automatic. However, the operator is compelled to observe the results of this procedure closely.
The interior orientation will normally be carried out automatically by the modern digital plotting system. A result control with statistical methods is essential. This also applies to the automatic tie point measurement as it is not guaranteed that the tie point detection is executed automatically for the complete area, including an sufficient amount of points.
At present the control point measurement has to be executed by an operator as the identification problem of the control points is not generally solved. Although the point measurement is normally supported by matching algorithms. Whether or not the control point measurement will retain its significance in the future remains to be seen as in connection with the DGPS-observations of the projection centres a far-reaching waive of the control points may become possible (Ackermann, 1997).
Due to the high grade of automation within the digital-automatic aerial triangulation measurement the general opinion is (Ackermann, 1995; Braun 1996) that the aerial triangulation executed in this manner will be more economical. It is also expected that the precision of the measurement reaches at least the same level as provided by the analytical measurement (Förstner, 1995) or delivers even better results (Ackermann, 1995).

3. THE START OF THE DIGITAL AERIAL TRIANGULATION

From about 1995 photogrammetrical systems have been available on the market, being implemented for the described far-reaching automatized measurement procedure for the aerial triangulation (e.g.: Krzystek et al., 1995; Mayr, 1995; Tsingas, 1995). The first positive results have been published.
AWP decided to indulge in this development at an early stage in order to ensure on the one hand a broad foundation from the start of the digital photogrammetry and on the other hand reap the benefits from the foreseen advantages.
A scanner and a work station for the triangulation measurement have been acquired in order to carry out this project. The scanner SCAI (Carl Zeiss) is working with an INDY-PC (Silicon Graphics) and uses the program PHODIS-SC (Carl Zeiss). The work station for the triangulation measurement consists of an INDY-SC (Silicon Graphics) on which the program packet PHODIS-AT (Carl Zeiss) has been installed. A hard disk capacity of 65 G Bytes is available to carry out the projects. The adjustment is carried out by the program PAT-B (INPHO).

4. FIRST PRACTICAL EXPERIENCES

In order to go into production at AWP some internal preparatory work was necessary. The actual independent working steps had to be connected with one another in order to guarantee a homogeneous and continual work flow. Following this the navigation data and the control point information must be available, the logistic for the control of the automatic procedures must be acquired and a sequential work planning according to the flow chart (Table 1) had to be built up.
Significant importance is attached to the training of the employees who are for the first time having contact with digital pictures and their processing techniques. Accordingly voluminous is the vocational training of the operators as they should know the principal flow within the digital photogrammetrical measuring programs to ensure early recognition in the lack of quality.

The described working procedure has been set into practice. In order to acquire full optimation the gained experience was hereby directed straight into the planning process. Following special hints regarding this work flow are stated hereafter.
Far-reaching automation for the practical work on the scanner (Figure 1) has been achieved by the use of comprehensive scanner software. The determination of the scan-parameter, in order to acquire the desired radiometric result of the analogue-digital transformation, requires fundamental knowledge of image processing. Though the digital aerial triangulation does not need extra ordinary or special requirements regarding the quality of the digital images.

Figure 1: Scanner work station SCAI.

Work on the aerial triangulation station begin firstly with the block preparation. In addition to this the logistical flow for large projects has to be determined. The navigation data acting as approximative data of the exterior orientation are imported into the survey project. The calculation segments for the automatic measurement are determined and the control points to be measured are integrated into the system.
The automatic measurements cover the calculation of the pyramids, the measurement and calculation of the interior orientation and the tie point measurement. The minutes of these work steps are to be sifted through regarding control of any irregularities. Subsequently missing connections between the images must be produced by means of half automatic point measurement. The control point measurements are carried out parallel to this. This measurement is supported by least square matching. Due to the two dimensional working of the matching algorithms not every control point is suitable for such a measurement. Automated control point recognition would surely be helpful in these cases.
Adjustment with the aerial triangulation program follow the measurement and if applicable necessary finishing work.

5. RESULTS

The first aerial triangulations that have been carried out have shown that the automatic digital aerial triangulation procedure selected by AWP is suitable for the practice. In the meantime some projects (Table 2) have come to an end. Analytical comparative measuremens on two projects are available.

Project	Picture scale	Focal length [cm]	Number of stripes	Number of Pictures	Control points Position hor./vert.	Terrain points	Blunders [%]	DGPS	σ_o [µm]	rms_x [µm]	rms_y [µm]
A	1 : 3000	30	1	16	9/9	1860	2,5	-	2,6	1,1	2,0
B	1 : 3500	15	9	93	11/11	10902	9,8	X	5,4	2,0	4,0
D	1 : 4000	30	3	23	5/5	3019	5,0	X	5,1	1,9	3,7
D [an]	"	"	"	"	"	143	-	X	5,0	2,4	4,1
C	1 :15000	30	6	61	81/129	9491	8,4	-	6,3	3,5	4,8
F	1 :15000	30	5	39	74/74	2739	6,5	X	6,2	3,5	4,2
F [an]	"	"	"	"	76/76	450	-	X	4,7	3,3	3,2
E	1 : 4000	30	16	484	73/73	54850	11,1	X	3,3	1,5	2,3

Table 2: Adjustment results.

For the digital aerial triangulation images have been digitized with a resolution of 28 µm. Table 2 states the sigma naught (σ_o) and the root mean square values of the photogrammetric observations (rms_x, rms_y).
It must be pointed out, that these projects are not designed for scientific researches. Relevant peculiarities (e.g. way of control points) have had quite a considerable influence on the adjustment results. Without treating the individual projects in detail the following results have been produced.
The reached accuracy complies in all cases with the requirements resulting out of the projects.
On comparison with analytical aerial triangulation it is found that similar accuracy can be reached. Special circumstances regarding the control points were give for project F leading to a deterioration of the digital adjustment results.
The number of the blunders regarding the tie points is partly relatively high. In connection with robust adjustment methods these can be found and eliminated so that a clear adjustment result can be obtained.
The obtained image orientations from the digital aerial triangulation were experimentally transferred to analytical plotters. It was found that after the execution of the interior orientation the formed models were evaluatable. Controls at from the operator adjustable points resulted in no significant distortions of the models. The geometrical efficiency of the digital measurement can be regarded as comparable to the analogue procedure.
The principally existing potential for rationalisation given by the automation of the tie point measurement is at the moment being distorted through a higher organisational and increased testing necessity. This will surely be changing in the future.

6. FUTURE OUTLOOK

The employment of automatic measuring procedures in the digital aerial triangulation seams to be suitable for practical use as the efficiency compared with analytical measurement is at least equal. For the continuous further development of the procedure it is surely sensible to carry on the automation of the control point measurement. The development at the computer components (especially memory media) will as well lead to the fact that the future belongs to the digital-automatic aerial triangulation measurement.

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