Photogrammetrische Woche 1977
Institut für Photogrammetrie
Schriftenreihe, Heft 4, 1977

RESULTS OF A COMPARATIVE AERIAL TRIANGULATION WITH PLANICOMP, MONO- AND STEREOCOMPARATOR

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1. Introduction

Today several methods of aerial triangulation are used in practice which can be characterized by the interaction of the plotting instrument and the corresponding computational process. According to the existing conditions either the instruments or the computational methods may demand the greater part of the work (see fig. 1).

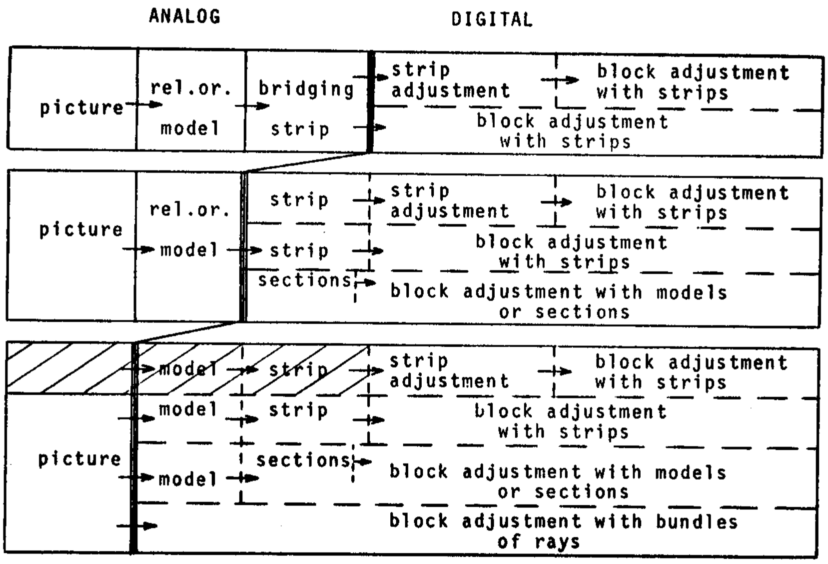

Fig. 1 Schematic diagram of the methods of aerial triangulation (from ACKERMANN |1|)

Formerly, aerial triangulation could only be performed with so-called universal plotters with base change since then the computers offered only a limited potential. Along with the rise and the rapid development of electronic computers effective methods for strip and block adjustments have been developed. Therefore the main part of aerial triangulation was transferred away from the instruments to the computational field so that the measurement as such could significantly be simplified. Today the measurement is done more or less exclusively with conventional stereoplotters or comparators. Universal plotters are no longer necessary and are no more used in their original way.

Finally another development on the instrumental field, namely the analytical plotter, has to be mentioned which has started already 20 years ago but has not been very successful up to now. This instrument offers a number of remarkable advantages for the application in aerial triangulation. These advantages are mainly based on the fast measurement, on the extensive checks which can be performed already during the measurement, on the automatic positioning of points, and on the possibility of an instant processing of the data with the connected computer.

But it is not possible to give a general recommendation for a certain combination of plotter and computational method since a number of quite different aspects has to be considered. In order to contribute some thoughts to these considerations a report will be given about a comparative investigation of aerial triangulations with the Zeiss instruments PSK, PK1 and Planicomp C 100.

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After a short presentation of the test material and of the measurement the computations with all connected operational problems will be mentioned. Thereafter, the results will be presented and discussed. In the end some kind of an evaluation shall be attempted.

2. The test material

For the investigation the photography of the test Oberschwaben of the OEEPE (Organisation Européenne d'Etudes Photogrammétriques Expérimentales) has been chosen which is especially suited for aerial triangulation test purposes. In order to keep the effort in a reasonable dimension only a subblock of the wide-angle flight was used consisting of 5 strips with 26 photos each.

The subblock covers an area of about 25 x 60 km^2. The image scale is about 1:28 000 with a flying height of approx. 5000 m. All tie points within the block had been signalized as well as all trigonometric points. The latter ones may be optionally used as control points or as check points for calculating the absolute accuracy of the block adjustment (in the chosen subblock about 300 points, see fig. 2). More details about the test field Oberschwaben may be found in |4|.

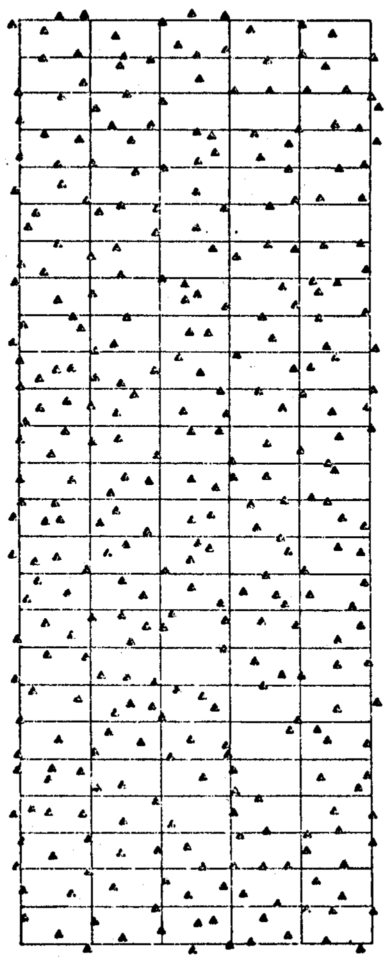

Fig. 2 Subblock Oberschwaben

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3. The measurement

In order to get results which are as reliable as possible the test conditions should be approximately the same with all three instruments. This would in principle have required the measurement of the photos or models by the same operator with all instruments. But for time and effort saving reasons the already existing measurement with the PSK was not repeated. Here, the original data of the observation by the Institute of Applied Geodesy in Frankfurt from 1970 were used. The measurements with the PK1 and the Planicomp were performed in July/August 1977 at Zeiss company in Oberkochen by Mr. Bettin of the Institute of Photogrammetry of Stuttgart University. For the best possible approximation of equal conditions at least the same glass diapositives as 1970 were utilized. No more preparational work was necessary since the marking and numbering of the points to be measured had already been done in 1970 on paper prints which were available also for the present investigation.

3.1 The measurement with the PSK

During the original observation with the PSK, six natural points per model were measured for the numerical relative orientation, in addition to the signalized points. The setting of the image points was generally done in both images independently (monoscopic). The stereo-view was only used for identification purposes.

The time of measurement of about 1 3/4 hours per model for an average of 22 points seems to be relatively high (see table 1). One reason besides others may be that the measurement was not performed under productional conditions but under the aspect of the special background of the investigation. In addition, for each point which was not visible an auxiliary point had to be chosen and also the six orientation points had to be selected during the measurement. Finally it has to be mentioned that also the coinciding procedure takes quite some time at the old PSK instrument. There is no information available about the setting accuracy of the image points. For the comparison with the remaining measurements the observation of a different photography - at the same time and with the same PSK - was used (see table 2).

Instrument	Number of models images	Number of points	Total time	Points per mod./image	Time per mod./image	Time per point
PSK	207	4650	360^h	22.5	104^m	277 sec
PK1	120	2800	$28^h\ 40^m$	23	14.3^m	37 sec
Planicomp	125	2000	$39^h\ 46^m$	16	19.1^m	72 sec
Planimat	9	-	-	16	32^m	120 sec

Table 1 Measuring times

Instrument	Eye piece's magnification	Number of points	Year	Setting accuracy x(μm)	Setting accuracy y(μm)
PSK[1)]	16 x	6000	1970	1.4	1.5
PK1	20 x	233	1977	1.4	1.6
Planicomp[2)]	16 x	68	1977	0.5	0.8

[1)] different images and different operator
[2)] from grid measurements

Table 2 Setting accuracy

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3.2 The measurement with the PK1

While measuring the photos with the PK1 it was realized that signalized points are not very well suited for monocomparators although they are often referred to as perfectly marked points. Only in some cases it was possible to observe all the points in one image. Mainly one or more point groups were not visible or could not clearly be identified. When also those points are considered which turned out erroneous in the later computations it means that with the PK1 in comparison with the PSK about 2 points less per model were measured. The percentage of failing control points was about four times larger than that of failing tie points (11 % to 3 %, see also table 8).

One reason for this may be because the tie points had been signalized as double points with almost the same distance in north-south direction while the trigonometric points had had larger targets but only in special cases had been attached with auxiliary identification targets. Therefore it seems to be necessary when using monocomparators in combination with signalized points to accept an increasing effort for the measurement or to use additional identification strips in the terrain or to signalize the points in a special geometric configuration.

The time for the measurement with the PK1 amounted to some 14 min. per photo containing an average of 23 points (see table 1). The setting accuracy derived from double measurements of 10 photos showed about the same results as the stereocomparator PSK did (1.5 µm for a single setting in x or y).

3.3 The measurement with the Planicomp C 100

The measurement with the analytical plotter Planicomp was performed by taking advantage of the various possibilities of the instrument. Due to the special character of the test field every first model of a strip could be absolutely orientated. All remaining models were connected by common tie points to the preceding model. If possible, an additional absolute orientation was performed which normally served only for a check of the residuals. After about every fifth model the parameters of the orientation were introduced into the computations and thus were effective for the following models.

If a model contained less control points than required for an absolute orientation at least the residuals at the available control points were shown besides the residuals at tie points. This procedure is of advantage for the following block adjustment since all tie points and all control points have been checked within the strip. Therefore these points are free from gross errors which occur because of numbering errors, mixing-up of points, etc.

But it has to be mentioned that an effective checking down to an accuracy of some ten centimeters is only possible if a complete absolute orientation can be performed after bridging a certain number of models. Otherwise the residuals at common points would amount to some meters because of the inevitable strip deformation and still these points are not incorrect. In these cases so-called "small gross errors" cannot be detected.

For the present investigation the practical measurement was basicly performed in the non-orientated model. That means that no independent relative orientation was measured and calculated but that the coordinates were observed similarly to the procedure in stereocomparators. These image coordinates were then used for the following computation of the relative orientation, of the model connection, and eventually of the absolute orientation. When tie points were measured the common points of two models were automatically positioned by the instrument so that it was only necessary to remove the parallax in the second image of a model. This procedure seems to be faster than a separate relative orientation and an independent measurement of the points in the orientated model, at least for only a few points per model. But this question was not investigated further.

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For a test of the condition and the accuracy of the Planicomp a calibration measurement was performed before the practical project started. Two different grid plates with 9 points and 25 points, respectively, were used. From the grid measurements a setting accuracy of about 0.7 µm was achieved (see table 2). But this value is not comparable with the setting accuracy of the PSK or PK1 since the double measurements were done immediately one after another while with the comparators the coordinates were observed in two independent series.

The root means square values of the residuals at grid points after the calibration ranged from about $m_{x,y}$ = 2 µm to $m_{x,y}$ = 3 µm, with maximum values of 4 µm. As a result of the calibration, pitch values for the spindles, a shift of the zero-point, and a deviation of the axes from rectangularity were obtained. These values were automatically introduced into the following measurements of the models.

The measuring time was about 19 min. per model which is remarkably short. Compared with an analog instrument this value means an increase of the measuring speed of about 40 % (see table 1) and it is only about 30 % above the measuring time of an image with the monocomparator. In practice, the time required might even be less (about 15 min.) since in the present case a complete printout of the whole measuring procedure was issued which too required a considerable amount of time.

4. Computations

All computations were carried out at the Control Data computers of the computing centre of Stuttgart University. They included the processing of the measurements, the relative orientation, the strip adjustment, and the block adjustment by independent models and by bundles.

4.1 Preparation of the input data

Since the PSK data had already been used for block adjustments in the official test programme Oberschwaben no additional preparation was necessary. Within the relative orientation which had been computed by the IfAG at Frankfurt in 1970 the influences of lens distortion, of earth curvature and refraction, and of film shrinkage were corrected. The root mean square values of the y-parallaxes after the orientation amounted to about 4 µm, with approx. 22 points per model.

The data of the Planicomp measurement could also directly be used as input for the aerial triangulation programmes. The coordinates were corrected for the influence of lens distortion and of affine film shrinkage. Earth curvature and refraction was to be corrected within the block adjustment. After the relative orientation in the Planicomp a root mean square value of the y-parallaxes of about 3 µm was obtained for an average of 16 points, with maximum values of 10 µm. The absolute orientation could generally be performed with about 5 horizontal and 4 vertical control points per model. The adjustment yielded an accuracy of σ_0 = 10 µm with maximum values of the residuals of about 30 µm. After the model connection the root mean square values of the residuals at about 7 tie points amounted to m_x = 15 µm, m_y = 5 µm, and m_z = 25 µm. The maximum values were up to 50 µm in planimetry and 100 µm in height. But it has to be mentioned that in this case after about 5 models a complete absolute orientation was accomplished and the results were used for the following model observations.

Some more preparational work was required for the PK1 measurements. First of all, they had to be transformed into the fiducial marks' coordinate system by simultaneously applying corrections for lens distortion, earth curvature and refraction, and affine film shrinkage. These so-called reduced image coordinates were used as input data for the bundle block adjustment.

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For the aerial triangulation with independent models the model coordinates had to be computed by numerical relative orientations. During these computations about 50 point measurements turned out incorrect. 20 measurements could be corrected since only their point numbers had to be changed but 30 points remained incorrect (10 of them were control points) and had to be eliminated. For 2 models the relative orientation failed because of too many gross errors. Since during the block adjustment another 2 models turned out faulty a total of 5 images had to be re-observed. The y-parallaxes after the orientation showed the usual magnitude. The mean values were m_{py} = 2.8 µm for about 14 points per model. This means that the model coordinates of all 3 instruments used for this investigation should be considered equally accurate.

4.2 Strip adjustments

All strip adjustments by independent models were accomplished with the computer programme STRIM-43-P. This programme has especially been developed for the application with the Planicomp and the HP 21 MX computer. It is based on exactly the same principles as the well-known block programme PAT-M 43. The only restrictions are that the models have to be measured in the sequence of the strip-formation, that one model can only be connected to the preceding and the following one, and that the strip can contain not more than 80 models. The programme can be executed in the background of the HP 21 MX which means that the Planicomp can still be used for measurements.

Two different control point variations were investigated. In the first one all available trigonometric points were used as control points and in the second one 6 models were bridged without control (i = 6, see fig. 3). In the latter case all unused trigonometric points served for the calculation of the absolute accuracy of the strip adjustment.

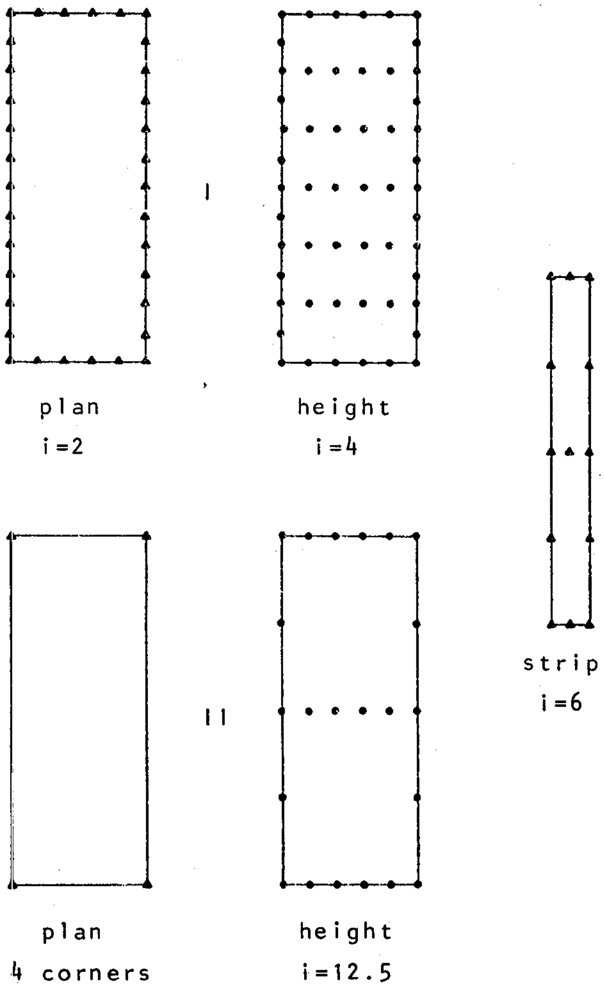

Fig. 3
Control point versions

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Two strips of the Planicomp measurements were errorfree so that the first adjustment run was already successful. For the remaining 3 strips two adjustment runs were required because of one double numbering of a point and incorrect connections at one projection centre and at two control points. Although the model coordinates were already referring to the terrain scale one adjustment run required 2 complete iterations (horizontal and vertical) because of the correction for earth curvature and refraction.

No information can be given about the effort of data-clearing of the PK1 measurements since the strip adjustments were only performed after the block adjustments where all gross errors had already been eliminated. For the final result 3 complete iterations were necessary.

4.3 Block adjustments

The block adjustments were accomplished with the small programme version of PAT-M 43 which too has been developed especially for the Planicomp (KLEIN |3|). Three different control point versions were distinguished (see fig. 3):

1. All available control points used,
2. Dense perimeter control in planimetry and height control points in chains with a distance of 4 models (i = 2 and i = 4), and
3. Four horizontal control points in the corners of the block and 3 chains of height control points.

For the adjustment of the Planicomp block 3 computer runs were required. 25 connections at tie points had to be eliminated, but always between two strips and not within a strip.

The data-clearing for the PK1 block required some more time since more errors occured. One control point showed residuals of about 1.5 km and at 8 control points the connection to one model was eliminated. 8 model connections were incorrect between two strips and 4 within a strip. In addition, one perspective centre had to be disconnected. In total 4 adjustment runs were required. This is still a satisfactory result but mainly depends on the fact that during the relative orientation already part of the gross errors could be corrected.

The experiences from the relative orientation were also used for the block adjustment with bundles which was performed with the computer programme PAT-B |4|. All those points could be corrected before the block adjustment which had turned out incorrect during the relative orientation. Anyway, the detection of gross errors within a bundle adjustment is still a little bit more complicated than with independent models. The residuals in the images are not as regular as in the models. In addition, single points cannot simply be carried through the adjustment but have to be eliminated completely. In total, the bundle block adjustment required 4 runs. About 20 points were incorrect and 60 points were only measured in one image.

4.4 Computing time

Finally, some remarks may be made about the computing time. It is not intended to discuss the absolute values but attention shall be drawn to the comparison between different versions (see table 3).

A remarkable result is that the special strip adjustment programme STRIM is about 3.5 times faster than the universal block programme PAT-M, applied to the same strip. Another statement says that with PAT-M and 2 horizontal and 2 vertical iterations the data organisation requires about 1/3 of the computing time and every additional iteration (horizontal and vertical) another 1/3 of the time. One more iteration means therefore an increase of the computing time of about 35 %.

Program	Number of models images	Number of iterations	CPU-time	System-time	Ratio	Ratio
Strip adjustment:						
STRIM	25	4	0.23 sec/mod.	0.42 sec/mod.	1	-
PAT-M	25	4	0.46 sec/mod.	1.48 sec/mod.	3.5	-
Block adjustment:						
PAT-M	3 x 25	4	0.38 sec/mod.	0.78 sec/mod.	1	-
PAT-M	3 x 25	6	0.51 sec/mod.	1.07 sec/mod.	1.4	1
PAT-B	3 x 26	3	1.26 sec/image	2.83 sec/image	-	2.5

Table 3 Computing times at the CDC 6600 computer

If a bundle block adjustment shall be performed instead of an adjustment with independent models the final result with the same accuracy (3 iterations) requires a 2.5 times higher computing time. However, when comparator measurements are used and the models are formed analytically the computing time for the relative orientation has to be considered, too. But also then the difference remains in the order of 1:2.

5. Results of the adjustments

The results of the various strip and block adjustments including the method of self calibration are presented in the tables 4 to 10 which in the following shall be discussed in more detail.

Instrument	n_{pp} plan	n_{pp} height	n_{obs}	Number of points 1-fold	2-fold	total	σ_{oL} µm	σ_{oH} µm	$\bar{v}_{model\ pts.}$ x,y(µm)	z(µm)	$\bar{v}_{persp.cent.}$ x,y(µm)	z(µm)	$\bar{v}_{contr.pts.}$ x,y(µm)	z(µm)
PSK	82	71	461	62	200	262	6.8	10.1	5.9	7.1	13.2	3.4	6.2	10.1
PK1	70	61	409	73	168	242	6.4	9.7	4.6	6.5	12.3	4.7	5.9	9.1
Planicomp	75	64	448	56	196	252	8.4	12.6	6.0	8.8	17.3	4.4	7.8	12.2

n_{pp} = Number of control points σ_0 = Standard deviation of unit weight

n_{obs} = Number of observations $\bar{v}$ = Root mean square values of the residuals

Table 4 Results of strip adjustments with independent models
All control points used
Mean values from 5 strips with 25 models each

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Instrument	n_{PP} plan	n_{PP} height	n_{VP} plan	n_{VP} height	σ_{oL} µm	σ_{oH} µm	$\bar{v}_{model\ pts.}$ x,y(µm)	$\bar{v}_{model\ pts.}$ z(µm)	$\bar{v}_{persp.cent.}$ x,y(µm)	$\bar{v}_{persp.cent.}$ z(µm)	Abs. accuracy x,y(µm)	Abs. accuracy z(µm)	Relation plan	Relation height
PSK	15	14	65	56	6.3	9.2	3.8	5.4	12.8	3.2	10.2	22.7	100%	100%
PK1	14	13	56	48	5.4	9.1	3.2	4.9	12.6	5.0	11.8	26.4	116%	116%
Plani-comp	15	14	61	53	7.4	11.6	4.5	6.9	15.1	4.2	13.3	29.6	130%	130%

n_{PP} = Number of control points

n_{VP} = Number of check points

σ_0 = Standard deviation of unit weight

$\bar{v}$ = Root mean square values of the residuals

Table 5 Results of strip adjustments with independent models
Control point version i = 6 (see fig. 3)
Mean values from 5 strips with 25 models each

5.1 Strip adjustments

In table 4 and 5 the mean values of all 5 strips are shown for both control point versions (i = 1 and i = 6). These values are mainly referring to the accuracy and to the number of points involved in the adjustments. When the σ_0 values and the root mean square values of the residuals for the three instruments are compared it is clearly visible that they are steadily increasing in the sequence PK1 - PSK - Planicomp. This means practically that the accuracy of the model coordinates is different for every instrument.

Considering the absolute accuracy (table 5) the PSK shows the smallest values. The ratio of the accuracy in the sequence PSK - PK1 - Planicomp is then (for planimetry or height) approx. 1 : 1.15 : 1.3. Compared with the PSK the Planicomp is not quite as accurate as may be expected, but compared with the PK1 the difference of about 15 % is not unusual. More information shall not be obtained from the strip adjustments.

Control version[1]	Instrument	n_{PP} plan	n_{PP} height	n_{VP} plan	n_{VP} height	σ_{oL} µm	σ_{oH} µm	$\bar{v}_{model\ pts.}$ x,y(µm)	$\bar{v}_{model\ pts.}$ z(µm)	$\bar{v}_{persp.cent.}$ x,y(µm)	$\bar{v}_{persp.cent.}$ z(µm)	$\mu_{x,y}$ µm	μ_z µm
0	PSK	321	279	-	-	7.1	10.0	5.6	7.7	13.4	3.4	(6.3)	(10.8)
	PK1	285	248	-	-	6.7	9.3	5.1	6.7	13.3	5.0	(5.8)	(9.4)
	Plani-comp	304	265	-	-	8.5	11.9	6.6	8.8	17.4	4.7	(7.6)	(11.8)
I	PSK	33	57	287	222	6.9	8.9	4.7	6.0	13.3	3.6	10.9	15.1
	PK1	33	57	252	191	6.3	8.4	4.2	5.1	13.1	5.1	13.4	14.9
	Plani-comp	33	56	271	209	8.1	11.0	5.5	7.3	15.9	5.0	14.4	17.6
II	PSK	4	27	316	252	6.0	8.9	4.1	5.9	13.3	3.5	37.2	18.3
	PK1	4	27	281	221	5.2	8.3	3.5	4.9	13.1	4.6	41.6	25.6
	Plani-comp	4	27	300	238	7.1	11.0	4.7	7.2	15.7	4.7	36.0	21.8

[1] Version 0: All control points used
Version I: Planimetry i = 2, height i = 4(2)
Version II: Planimetry 4 points in corners, height i = 12.5(6)
(see fig. 3)

Table 6 Accuracy of block adjustments with independent models
Wide-angle subblock Oberschwaben

5.2 Block adjustments with independent models

The results of the block adjustments with independent models mainly confirm the relations which were found in the strip adjustments. σ_0 and the root mean square values of the residuals at model points are for the instruments PSK - PK1 - Planicomp in a ratio of about 1 : 0.9 : 1.2 (see table 6).

As for the absolute accuracy some differences can be realized (see table 7). For control point version I the relation of the planimetric accuracy of PSK - PK1 - Planicomp is about the same as in the strip (1 : 1.2 : 1.3) but in height PSK and Planicomp differ only by about 17 % and PK1 and PSK show about the same accuracy.

When only 4 horizontal control points in the corners of the block and 3 chains of vertical control points are available (version II) the accuracy relations are still more different. Here, the Planicomp is significantly superior to the PK1 and almost as accurate as the PSK.

The absolute accuracy of the PK1 which is not quite satisfying compared with the PSK may be explained with the fact that the connections within the block are not as intense as in the PSK block (see table 8). Firstly, the PK1 block contains already 60 points less than the PSK block and secondly, it contains 60 single points more which have no influence over the redundancy of the adjustment.

When both control point versions I and II are considered together the mean accuracy ratio for the 3 instruments PSK - PK1 - Planicomp is about 1 : 1.2 : 1.15 (planimetry and height). This result can be called quite satisfactory.

Control version[1]	Instrument	σ_{oL} µm	σ_{oH} µm	$\mu_{x,y}$ µm	μ_z µm	$\mu_{x,y}$ m	μ_z m	Relation plan %	Relation height %
Independent Models									
I	PSK	6.9	8.9	10.9	15.1	.305	.424	100	100
	PK1	6.3	8.4	13.4	14.9	.375	.418	123	99
	Planicomp	8.1	11.0	14.4	17.6	.403	.494	132	117
II	PSK	6.0	8.9	37.2	18.3	1.042	.513	100	100
	PK1	5.2	8.3	41.6	25.6	1.165	.717	112	140
	Planicomp	7.1	11.0	36.0	21.8	1.008	.611	97	119
Bundles									
I	PK1	4.8		12.2	16.0	.352	.461	115	109
II	PK1	3.5		38.6	20.0	1.116	.578	107	113

1) Version I: Planimetry i = 2, height i = 4(2)
Version II: Planimetry 4 points in corners, height i = 12.5(6)
(see also fig. 3)

Table 7 Absolute accuracy of block adjustments
Wide-angle subblock Oberschwaben

Instrument	Method	Contr.pts. plan	Contr.pts. height	Observations	Block points 1-fold	2-fold	3-fold	4-fold	5-fold	6-fold	total
PSK	PAT-M	321	279	2307	186	605	25	209	-	-	1025
PK1	PAT-M	285	248	2045	248	520	35	163	-	-	966
Planicomp	PAT-M	304	265	2241	188	611	29	186	-	-	1014
PK1	PAT-B	291	254	2856	-	225	356	48	42	156	827 [1]

[1] no perspective centres

Table 8 Number of points in the block adjustments

5.3 Block adjustment with bundles

In the official Oberschwaben test the unexpected result had been obtained that the bundle block adjustment in any case was inferior to the method of independent models. This statement is no longer valid for the PK1. Here, the bundle method is about 10 % to 15 % more accurate (see table 7). A possible reason for this may be the different measuring procedures. With the PK1 the image coordinates are observed for the whole image at a stretch while with the PSK the two parts of one image had to be transformed together. It is possible that this procedure produced some systematic errors which influenced the accuracy relations. Table 9 contains more information about the bundle block adjustment but shall not be discussed in detail.

Control version	n_{PP} plan	n_{PP} height	n_{VP} plan	n_{VP} height	σ_o µm	$\bar{v}_{image\ pts.}$ x(µm)	$\bar{v}_{image\ pts.}$ y(µm)	$\bar{v}_{contr.pts.}$ x(µm)	$\bar{v}_{contr.pts.}$ y(µm)	$\mu_{x,y}$ µm	μ_z µm
0	291	254	-	-	5.9	4.6	4.3	5.2	5.9	-	-
I	33	57	258	197	4.8	3.5	3.0	3.6	3.8	12.2	16.0
II	4	27	287	227	3.5	2.7	1.8	2.5	1.7	38.6	20.0

Table 9 Accuracy of block adjustments with bundles
Wide-angle subblock Oberschwaben

For a better interpretation of the accuracy relations within the blocks the vectors of the horizontal residuals at tie points are shown in grafical form in the figures 4 to 7 for the control point version I (i = 2). The adjustment with independent models shows for all 3 instruments approximately the same tendency with only a different magnitude of the vectors. There is a significant systematic effect which must be caused by image errors. Only the results of the bundle block adjustment (fig. 7) expose a slightly different behaviour. But the main systematic effect is also clearly visible.

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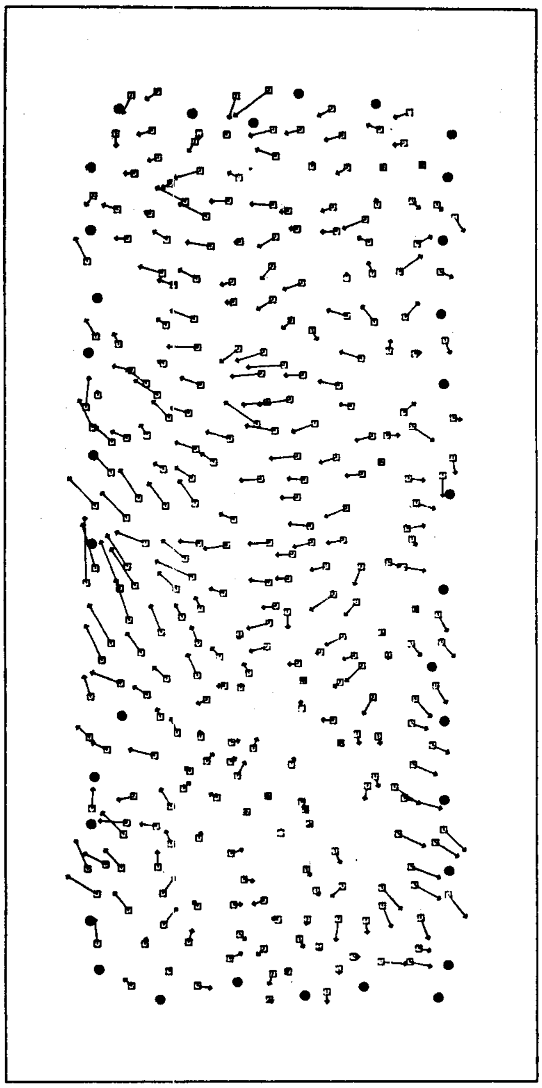
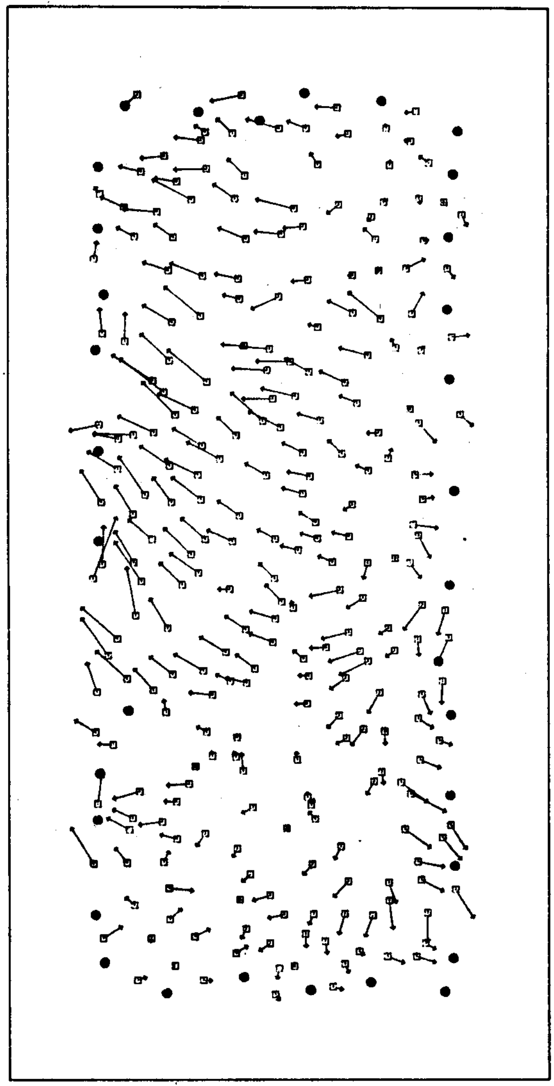




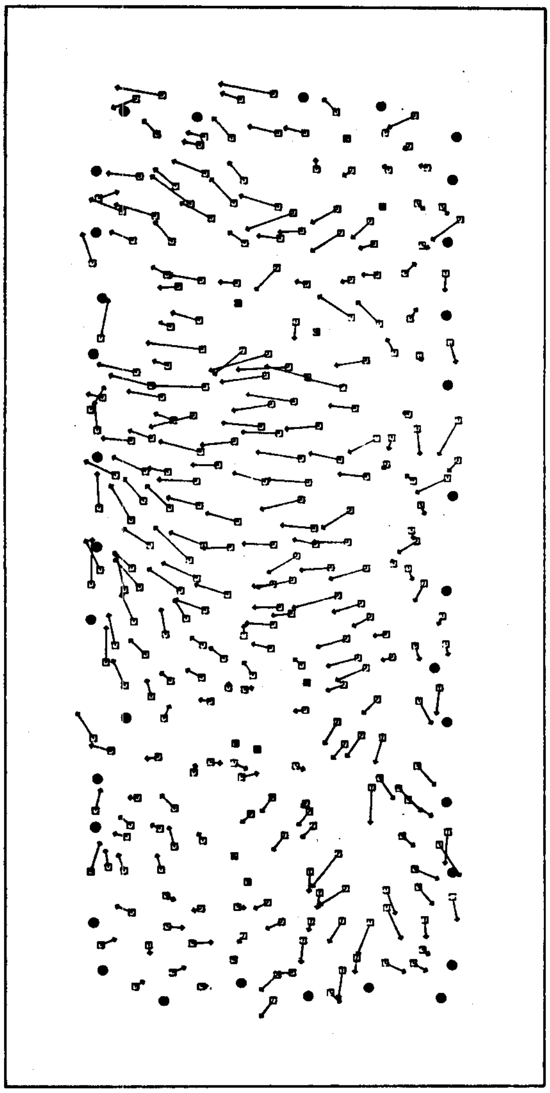
= 0.5M

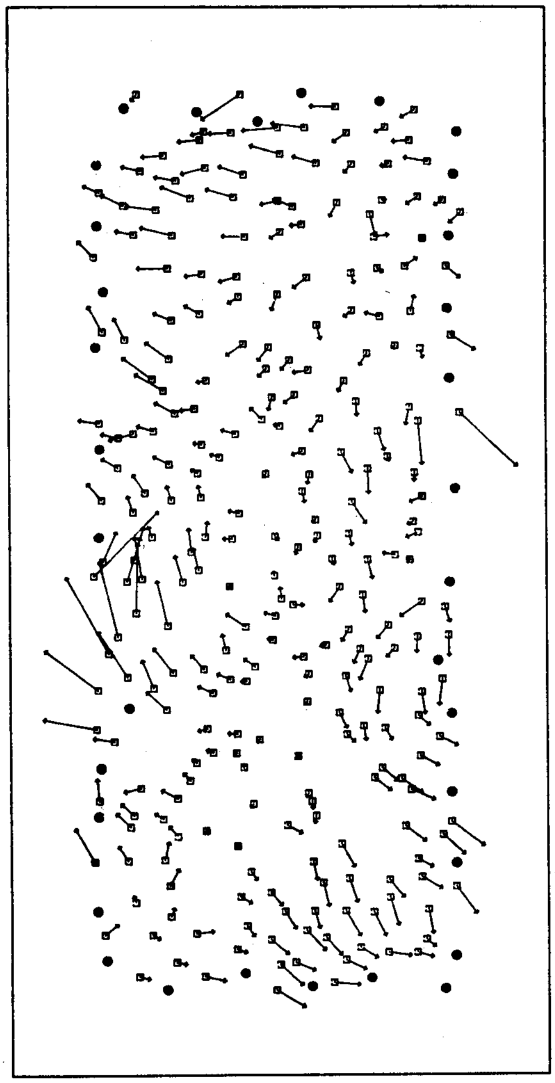
Fig. 4

PSK measurement, i = 2
Adjustment with independent models

Fig. 5

PK1 measurement, i = 2
Adjustment with independent models





= 0.5M

Fig. 6

Planicomp measurement, i = 2
Adjustment with independent models

Fig. 7

PK1 measurement, i = 2
Adjustment with bundles

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5.4 Self calibrating block adjustment

The self calibrating block adjustment was only applied to the method of independent models with control point version I (see fig. 2). The results are presented in table 10. The additional parameters for the self calibration have been chosen according to EBNER |2|. The parameters were arranged in two groups, one which varied from strip to strip and one which was fixed for the whole block. Parameters which were insignificant in all strips were not considered at all.

Instrument	without self calibration				with self calibration				accuracy improvement				Relation with self calib.	
	σ_{oL} µm	σ_{oH} µm	$\mu_{x,y}$ µm	μ_z µm	σ_{oL} µm	σ_{oH} µm	$\mu_{x,y}$ µm	μ_z µm	σ_{oL}	σ_{oH}	$\mu_{x,y}$	μ_z	plan %	height %
PSK	6.9	8.9	10.9	15.1	4.8	8.1	7.0	14.5	1.43	1.09	1.56	1.04	100	100
PK1	6.3	8.4	13.4	14.9	4.0	7.6	8.0	13.0	1.56	1.10	1.67	1.15	114	90
Planicomp	8.1	11.0	14.4	17.6	5.9	10.3	10.4	16.0	1.38	1.07	1.38	1.11	149	110

Table 10 Accuracy of block adjustment by independent models
Control point version I (plan i = 2, height i = 4)

In planimetry the accuracy improvement by self calibration is considerably large (about 40 % to 65 %) which is in accordance with previous experiences. In height there is only a slight improvement of about 5 % to 15 % due to a side overlap of only 20 %.

The Planicomp shows in planimetry the smallest improvement and the PK1 the largest one. This is not surprising since at the Planicomp already part of the systematic instrument errors had been corrected by the grid calibration measurements. The accuracy ratio for PSK - PK1 - Planicomp is now 1.0 : 1.15 : 1.5 (planimetry) and 1.0 : 0.9 : 1.1 (height). Subsequently the accuracy of the Planicomp cannot yet reach up to the accuracy of comparators. The magnitude of the accuracy difference itself (50 % in planimetry) can be considered unexpected. If it is significant or not should be proved by additional tests.

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6. Conclusion

The aim of the present investigation was to gain experiences about the application of three different instruments for the measurement of aerial triangulations. At the end of this paper therefore an attempt for a valuation of the results shall be made.

First of all it can be stated that the analytical plotter Planicomp C 100 is very well suited for the application in aerial triangulation. Although the accuracy seems to be not quite as good as that of comparators, its great potential and universality - also regarding all kinds of checks -, its measuring comfort, its measuring speed, and its connected computer might be the crucial point for its practical use.

On the other hand, with the monocomparator PK1 an instrument with a reasonable price and high precision is available which too can very successfully be applied in aerial triangulation. The only reservations may be related to the use of signalized points. In this respect it could happen that quite a number of points cannot be identified clearly which in the end may also be costly. In addition, from an operational point of view the bundle block adjustment still seems to be more complicated than the independent model method which is caused by a larger computing time and a more difficult procedure for data-clearing. Finally one can say that monocomparators may only be efficiently applied in aerial triangulation in combination with a comfortable and precise point transfer equipment.

Compared with the monocomparator the stereocomparator PSK with its well-known technique and measuring principle has no problematic fields. The accuracy is practically the same for both instruments but for the PSK a considerably higher price must be accepted which may prevent its economic application.

The presented results do not allow a clear recommendation for one or another instrument. For all three instruments a very high accuracy could be proved which fully confirms their applicability in aerial triangulation. In practice therefore the aspects of economy and accuracy have to be considered very carefully. In any particular case it should be exactly investigated which equipment satisfies the present requirements best.

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Abstract

The measurements of aerial triangulations can be performed with different types of instruments, as comparators, analogue stereo plotters, or analytical plotters. The paper presents the results of aerial triangulations using the ZEISS instruments PLANICOMP C 100, PK1 and PSK. For the investigations a sub-block of the wide-angle photo flight of the test area Oberschwaben has been chosen which consists of 5 strips with 26 photos each. The strip and block adjustments were done with the Stuttgart computer programs STRIM-43-P, PAT-M 43, and PAT-B, based on the method of independent models and on the bundle method. The results are compared in respect to the accuracy as well as to the required time for the measurement and the computation.

Zusammenfassung

Für die Messung von Aerotriangulationen können verschiedene Typen von Auswertegeräten eingesetzt werden. Im vorliegenden Bericht werden die Ergebnisse vorgestellt, die aus Aerotriangulationen mit den ZEISS-Geräten PLANICOMP C 100, PK1 und PSK gewonnen wurden. Die Untersuchung erfolgte mit einem Teilblock aus 5 Streifen mit je 26 Bildern aus der Weitwinkel-Befliegung des Testgebiets Oberschwaben der OEEPE. Die Streifen- und Blockausgleichungen wurden nach der Methode der unabhängigen Modelle und nach der Bündelmethode mit den Stuttgarter Rechenprogrammen STRIM-43-P, PAT-M 43 und PAT-B durchgeführt. Die erhaltenen Ergebnisse werden sowohl in Bezug auf die Genauigkeit als auch auf den benötigten Zeitaufwand für die Messung und Berechnung miteinander verglichen.

Résumé

Différentes types d'appareils restituteurs peuvent être mis en oeuvre pour la mesure des triangulations aériennes. L'exposé présente les résultats donnés par les triangulations aériennes exécutées avex le PLANICOMP C 100 de CARL ZEISS, ainsi qu'avec le Monocomparateur PK1 et le Stéréocomparateur PSK. Les études se basèrent sur un bloc partiel de 5 bandes, comprenant chacune 26 photographies prises avec une chambre grand-angulaire au-dessus du terrain de test de l'OEEPE en Haute-Souabe. Les compensations par bandes et par blocs furent exécutées selon la méthode des modèles indépendants et selon la méthode des faisceaux, avex les programmes de calcul STRIM-43-P, PAT-M 43 et PAT-B de Stuttgart. La comparaison des résultats obtenus porte sur la précision, ainsi que sur la rapidité des mesures et des calculs.

Resumen

Para la medición de triangulaciones aéreas pueden emplearse varios tipos de restituidores. En esta conferencia se presentan los resultados obtenidos de aerotriangulaciones con los instrumentos de la casa ZEISS: Planicomp C 100, PK 1 y PSK 2. Los análisis se han llevado a cabo con un bloque parcial compuesto de 5 fajas de cada vez 26 imágenes y procedente de los vuelos realizados con cámara granangular de la región de ensayos "Oberschwaben" de la Organisation Européenne d'Etudes Photogrammétriques Expérimentales (OEEPE). Las compensaciones de fajas y bloques han sido realizados según el método de los modelos independientes y el de haces, con ayuda de los programas de cálculo de Stuttgart STRIM-43-P, PAT-M 43 y PAT-B. Se comparan los resultados obtenidos tanto en lo relativo a su exactitud como en cuanto al tiempo invertido para medir y calcularlos.

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