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

EXPERIMENTAL INVESTIGATIONS WITH THE ZEISS PLANITOP F2

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1. Introduction

In 1973 Carl Zeiss, Oberkochen, presented its new topografic stereoplotter Planitop F2 (fig. 1). The instrument has been designed for the use in medium and small scale grafical and numerical plotting and should complete the series of the existing analog instruments comprising the Planimat D2 and Planicart E2. The construction is based on a strict solution with three - dimensional mechanical space rods.

The most important fields of application for the Planitop are mentioned by SCHWEBEL |2|:

- Small scale and medium scale mapping
- Map revision
- Digitizing
- Aerial triangulation
- Photo interpretation
- Training

The Institute of Photogrammetry of Stuttgart University has recently performed an extensive instrument investigation with the Planitop F2 in order to get information about its accuracy and its applicability for different tasks. The result of this investigation shall be briefly presented in the following.

2. Grid measurements

For investigating the basic accuracy of the instrument several stereoscopic grid measurements with two different focal lengths (wide-angle and super-wide-angle) and with different tilts of the photo carriers were performed. The results of all 20 wide-angle and 10 super-wide-angle grid models are presented in table 1 and 2.

The wide-angle photography shows a planimetric accuracy of $m_{x,y}$ = 8.7 μm and a height accuracy of m_z = 7.6 μm = 0.05 ‰ of h, and the super-wide-angle photography shows the corresponding values of $m_{x,y}$ = 9.7 μm and m_z = 6.1 μm = 0.07 ‰ of h. The results are not influenced by different tilts of the photo carrier. But there is a significant systematic influence of the direction of the point setting over the residuals at grid points. In order to show this effect the mean residuals at all 45 grid points are presented in grafical form in the figures 2 to 5. The direction of the vectors clearly indicate the meandering procedure of the measurement.

3. Measurement of single models

More information about the Planitop's accuracy shall be received by the observation of single models with signalized points. Four wide-angle and four super-wide-angle models have been selected from the aerial photography of the test field Rheidt of the Photogrammetric Institute of Bonn University which were taken in 1969 and in 1975 at an image scale of about 1:11 000. Every model contains 23 point groups of 3 points each which had been signalized in the terrain by 30 cm x 30 cm plastic targets.

During the measurement with the Planitop only an approximate absolute orientation was performed. The final orientation was done numerically by a spatial similarity transformation using all points as ground control points. The summarized results are presented in table 3.

The planimetric accuracy with $m_{x,y}$ = 12.1 µm (wide-angle) and $m_{x,y}$ = 13.8 µm (super-wide-angle) may be called very good. Also the height accuracy with m_z = 17.2 µm = 0.11 ‰ of h (wide-angle) and m_z = 16.1 µm = 0.19 ‰ of h is satisfactory, but from the results of the grid measurements one may have expected a slightly better value.

A remarkable finding is that the planimetric accuracy is practically the same as the setting accuracy (which can be calculated on the base of double measurements). That is especially true in regard to the limited precision of the recorded coordinates of only 1/100 mm, to the relatively small magnification ratio between image and model scale (1.04 x to 1.52 x), and to the fact that the Planitop is only equipped with a free hand motion.

4. Determination of perspective center coordinates

For aerial triangulation with independent models the coordinates of the perspective centers of each model are required. Due to the arrangement of the rotation axes of the Planitop these coordinates are changing with the alteration of the relative orientation. Therefore they have to be determined for every model individually. Three different methods for the determination of the perspective centers have been investigated:

1. Computation by space resection
2. Placing the space rods in a vertical position
3. Simplified calculation by use of ϕ-readings.

The most important question in respect to the comparison of these 3 methods is the accuracy of the coordinate determination itself. This accuracy has been derived from multiple measurements of wide-angle and super-wide-angle grid models. Table 4 shows that with the two methods of space resection and vertical space rods practically the same accuracy can be achieved. But the accuracy itself - especially for wide-angle photography - is not entirely satisfactory. On the other hand the determination of the z-coordinates by the ϕ-readings is significantly poorer than by the remaining methods. The main reason for this is the low precision of the index for the ϕ-reading and the inaccuracety calibrated distance between the perspective center and the axis of the ϕ-rotation. But since this is a very simple and a very fast procedure these two problems should be solved for a successful application in practice.

5. Aerial triangulation

For the investigation of the accuracy of aerial triangulation with the Planitop a wide-angle subblock with 3 strips of 12 models each from the test area Oberschwaben of the OEEPE has been chosen. The scale of the photography is about 1:28 000, and all control points and tie points had been signalized in the terrain. In addition, artificially marked tie points were used in this investigation.

The results of the different versions of block adjustments which have been performed with the computer programme PAT-M43 are presented in table 5. The absolute accuracy which shows standard deviations of $m_{x,y}$ ≈ 50 cm to 60 cm (= 18 µm to 21 µm) and m_z ≈ 70 cm to 80 cm (= 0.15 ‰ to 0.20 ‰ of h) can be called quite satisfactory for small scale applications. Anyway, compared with precision plotters a significantly lower accuracy has to be accepted.

In small scale mapping the use of a statoscope is of great importance. The results of block adjustments with statoscope data are also included in table 5. When height control points are arranged after every 12 models and a statoscope is used almost the same height accuracy can be achieved as with control points after every 4 models and without statoscope.

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6. Plotting of contour line maps

This part of the investigation was performed with aerial photography of the test field Söhnstetten (see |1|). The terrain of this test field is very hilly and shows height variations of up to 70 m.

For a rigorous test of the accuracy of contour lines several profiles were used whose points have been determined by tacheometry in the terrain. Thus a total of about 500 height check points are available. Figure 6 shows a sketch of the area with the check profiles.

Two different methods of contour line plottings were investigated with the Planitop. In the first one the contour lines were directly plotted in the instrument at a scale of 1:10 000 which is equivalent to the image scale. In the second one the model was scanned in profiles and the contour lines were derived from a DTM with the use of the Stuttgart contour lines computer programme SCOP.

6.1 Direct plotting of contour lines

While directly plotting the contour lines in the model scale 1:10 000 with an interval of 5 m between contours they were simultaneously digitized. The digitized data were used for plotting the contours in a larger scale in order to allow a more accurate interpretation. In practice, this digitizing method may be used to be more independent from the small magnification range between image and model scale of the Planitop.

When comparing the profile points derived from the contour lines with those originally determined in the terrain a root mean square value of the residuals of $m_Z = 40.2$ cm was obtained. The residuals itself showed a significant systematic effect since nearly all check profiles were lower than the photogrammetrically derived profiles.

6.2 Automatic interpolation of contour lines

For the automatic interpolation of contour lines by means of computer programmes the stereoscopic model was scanned in the Planitop with a point interval of 1.5 mm along the profile (= 15 m in the terrain). The scanning was not automatically controlled but simply performed by using the free hand movement of the floating mark. The x-direction of the profile was defined by fixing the model carriage with strong magnets. The adjacent profiles were then established by a displacement of the carriage in y-direction the amount of which could be checked at the coordinate display of the Ecomat. The profile points were then recorded automatically by constant time or distance intervals.

The scanning data were used as input for the computer programme SCOP to compute a digital terrain model (DTM) which finally served for the determination and automatic plotting of the contour lines. For checking the accuracy of the contours the photogrammetric profile points could directly be interpolated with the SCOP programme using their known planimetric coordinates. Therefore no manual interpolation was required.

The root mean square values of the residuals amounted to $m_Z = 65$ cm. As for the direct contour line plotting the residuals were significantly systematic. One reason for the accuracy difference between the two methods could be that during the scanning the floating mark is generally kept above the terrain surface. And this effect may be greater when the scanning speed is increased which is normally true for automatic scanning. In addition, it may be mentioned that the size of the floating mark - referring to the terrain scale - is already 60 cm in diameter. This may also be of significant influence over the accuracy of the contour lines.

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7. Conclusions

The Planitop F2 is an instrument which on the one hand can be called a small conventional stereoplotter. On the other hand its fields of application can be extended by the use of auxiliary digitizing equipment. In the present investigation both aspects have been taken into consideration and special attention has been drawn to the achievable accuracy of the Planitop in different tasks.

In the conventional application field all requirements can be considered completely fulfilled. Especially the setting accuracy of the free hand motion is remarkably good. When using the digitizing equipment contour lines can also be plotted in larger scales. But in these cases they have to be revised manually or automatically in order to obtain a satisfactory quality.

Also in the fields of aerial triangulation the Planitop can be successfully applied when the accuracy requirements are adapted accordingly. But then it should be possible to determine the coordinates of the perspective centers more precisely. In this respect, also the method of ϕ-recordings should be made more effective by a more accurate ϕ-index and by a properly calibrated distance between ϕ-axis and perspective centers.

Finally two more recommendations may be suggested. The first one is to enlarge the eye-piece's magnification from 6 x to about 8 x and the second one to reduce the size of the floating mark to about 30 μm to 40 μm in diameter. Then it seems possible to make use of the full accuracy capacity of the Planitop F2.

References

|1| Schilcher, M.: A Comparison of the Accuracy of Several Contour Plots of the Söhnstetten Test Field. Schriftenreihe des Instituts für Photogrammetrie, Heft 4, S. 29-50, 1977.

|2| Schwebel, R.: Das topographische Kartiergerät Planitop F2. BuL 41, S. 234 - 240, 1973.

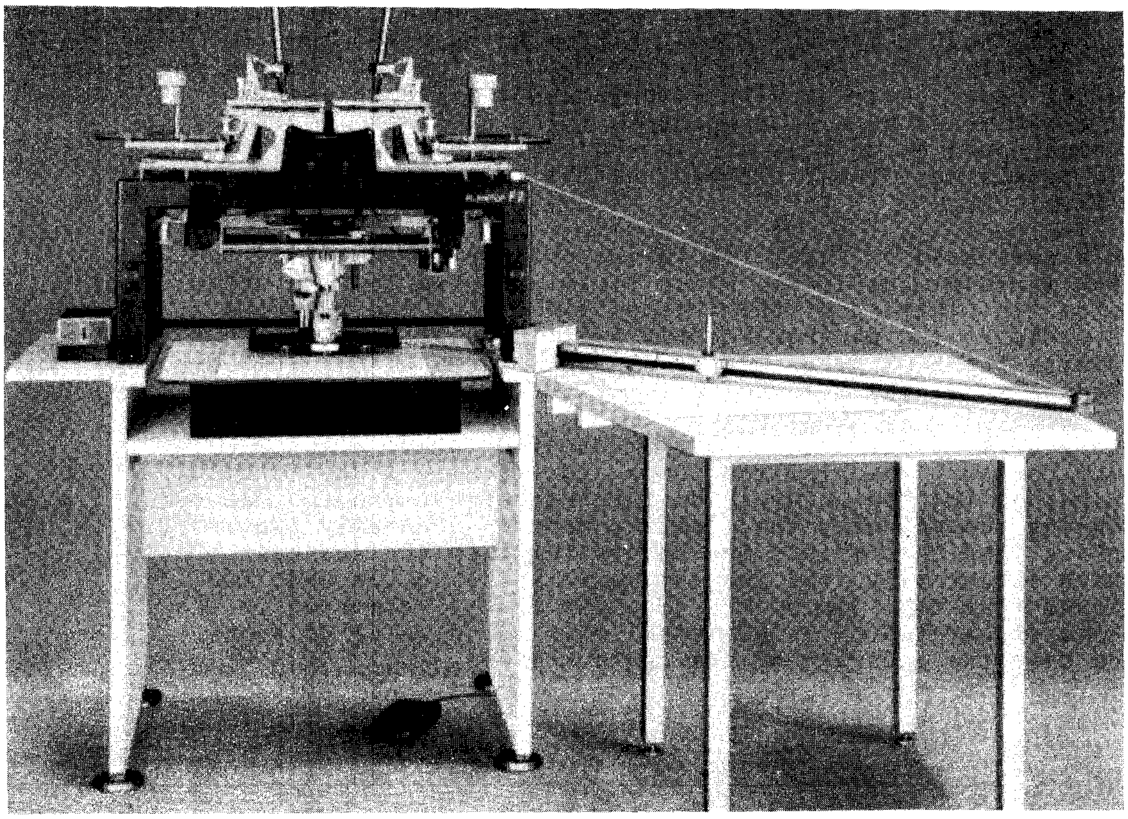

Fig. 1
PLANITOP F2 with table

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Model	m_x |µm|	m_y |µm|	m_z |µm|	Common tilts κ |c|	φ |c|	ω |c|
1	5.3	10.5	6.0	0	40	0
2	4.2	9.0	8.2	0	40	0
3	5.4	10.7	7.3	0	40	0
4	4.3	7.8	6.3	0	40	0
5	5.1	10.2	7.6	0	40	0
6	5.3	10.4	6.7	0	40	0
7	5.9	11.5	7.9	0	40	0
8	10.2	15.7	7.4	0	40	0
9	6.3	10.3	8.3	0	40	0
10	6.2	11.5	8.8	0	40	0
11	5.1	10.8	8.7	0	0	0
12	5.3	11.3	7.4	0	0	0
13	6.6	11.1	6.8	0	0	0
14	6.4	10.4	7.2	0	0	0
15	6.1	12.7	7.5	0	0	0
16	5.9	10.0	7.3	0	0	0
17	6.9	10.0	9.6	0	100	100
18	6.4	9.6	7.5	0	100	100
19	7.0	9.1	7.4	0	250	250
20	6.3	8.5	7.4	0	250	250
	6.2	10.7	7.6			

$m_{x,y}$ = 8.7 µm
m_z = 7.6 µm = 0.05 ‰ f

Accuracy after numerical absolute orientation with all 45 control points
Values referring to the image scale
Ratio between image and model scale = 1.44

Table 1 Accuracy of wide-angle grid measurements

Model	m_x |µm|	m_y |µm|	m_z |µm|	Common tilts κ |c|	φ |c|	ω |c|
1	7.3	9.9	4.8	0	0	0
2	9.1	10.1	11.0	0	0	0
3	9.0	12.3	7.4	0	0	0
4	9.2	12.5	5.7	0	0	0
5	11.1	15.5	5.3	0	0	0
6	7.9	9.7	4.5	0	0	0
7	6.4	9.3	5.1	0	100	100
8	7.0	9.3	4.8	0	100	100
9	5.9	9.5	4.7	0	250	250
10	6.6	10.8	4.4	0	250	250
	8.1	11.0	6.1			

$m_{x,y}$ = 9.7 µm
m_z = 6.1 µm = 0.07 ‰ f

Accuracy after numerical absolute orientation with all 45 control points
Values referring to the image scale
Ratio between image and model scale = 1.44

Table 2 Accuracy of super-wide-angle grid measurements

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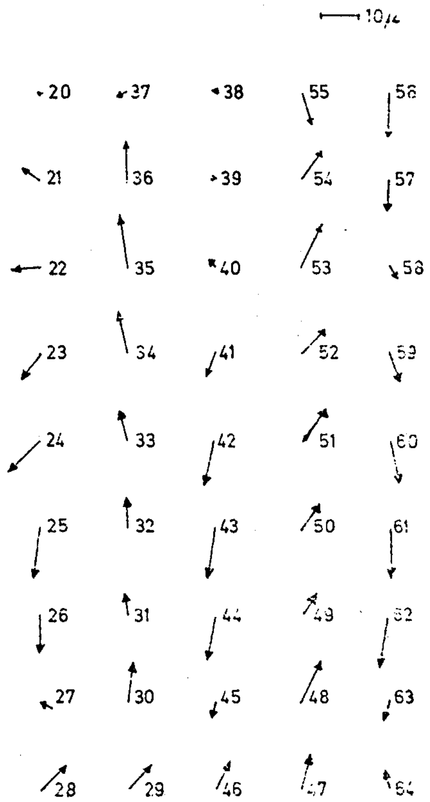

Fig. 2
Wide-angle grid measurements
Mean horizontal residuals
of 20 grid models

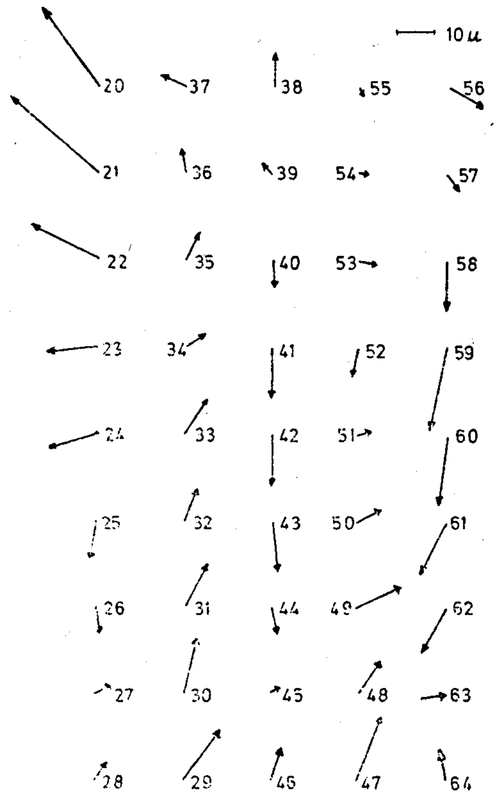

Fig. 3
Super-wide-angle grid measurements
Mean horizontal residuals
of 10 grid models

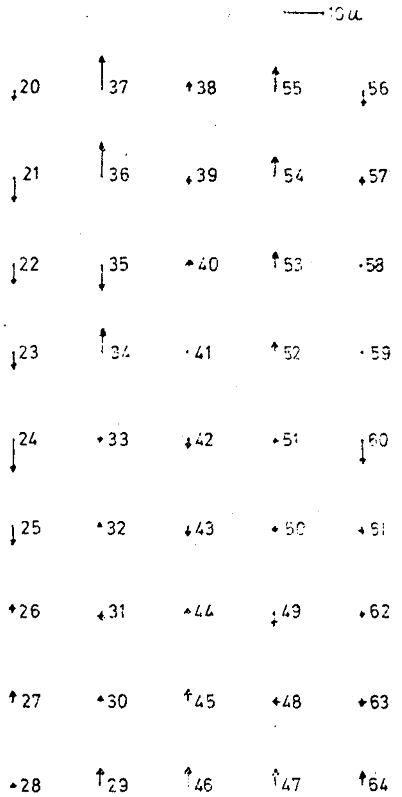

Fig. 4
Super-wide-angle grid measurements
Mean horizontal residuals
of 10 grid models

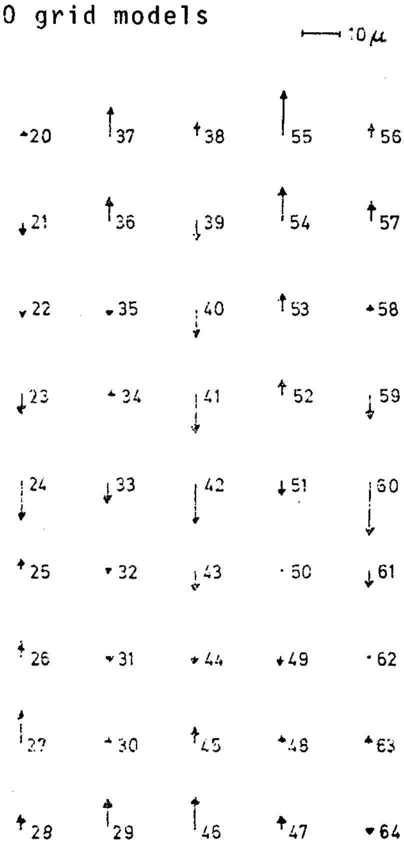

Fig. 5
Wide-angle grid measurements
Mean horizontal residuals
of 20 grid models

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	Stereopair	f [mm]	Image scale / Model scale	Number of pts.	$m_{x,y}$ [µm]	m_z [µm]	
WW	939/938	153	1:10 500 / 1: 9 874	65	11.0	19.6	Setting accuracy (from double measurements)
	938/937	153	10 500 / 9 343	65	12.6	12.8	m'_x = 11.2 µm
	876/874	153	10 500 / 10 222	60	12.7	11.1	m'_y = 14.0 µm
	874/873	153	10 500 / 11 165	65	12.1	19.9	m'_z = 7.5 µm
				$m_{x,y}$ = 12.1 µm m_z = 17.2 µm = 0.11 ‰ h			
SWA	248/244	85	1:11 000 / 1: 7 064	69	17.4	17.9	
	252/248	85	11 000 / 6 882	66	11.4	17.8	m'_x = 8.9 µm
	031/035	85	11 000 / 7 374	66	11.6	14.3	m'_y = 12.1 µm
	035/039	85	11 000 / 7 625	67	13.9	14.3	m'_z = 5.2 µm
				$m_{x,y}$ = 13.8 µm m_z = 16.2 µm = 0.19 ‰ h			
	All values referring to the image scale						

Table 3 Accuracy of single models with signalized points
Test field Rheidt, wide-angle (WA) and super-wide-angle (SWA)

Method		Left perspect. center			Right perspect. center		
		m_x [µm]	m_y [µm]	m_z [µm]	m_x [µm]	m_y [µm]	m_z [µm]
Space resection	WA	43.6	33.7	19.9	45.0	42.1	19.5
	SWA	17.8	21.4	12.7	17.4	26.5	11.8
Vertical space rods	WA	31.7	41.2	16.4	32.7	44.3	15.1
	SWA	15.6	17.3	7.0	14.5	18.1	14.2
ϕ-readings	WA	38.8	54.8	61.5	42.8	45.2	75.5
	SWA	18.8	14.5	78.2	8.4	25.0	57.1

Table 4 Accuracy of the determination of the perspective centers

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Version	Number of control points		Number of check points		σ_o		Absolute accuracy				
	x,y	z	x,y	z	x,y |μm|	z |μm|	$\mu_{x,y}$ |cm|	μ_z |cm|	$\mu_{x,y}$ |μm|	μ_z |μm|	μ_z ‰ h
I	83	71	-	-	15.9	13.8	25.1	24.1	9.0	8.6	0.049
II	18	23	65	47	17.7	14.3	49.3	82.8	17.6	29.6	0.167
III	18	23	66	50	17.3	14.2	59.9	68.1	21.4	24.3	0.138
IV	12	8	71	62	17.1	20.3	66.3	85.1	23.7	30.4	0.171

I All control points used

II Planimetry: perimeter control i=2b
Height: chains i=4b
Signalized tie points

III As II but with artificial tie points

IV With statoscope data
Planimetry: perimeter control i = 4b
Height: 2 chains i=12b

Table 5 Accuracy of aerial triangulation with independent models
Wide-angle subblock Oberschwaben
3 x 12 models, image scale 1:28 000

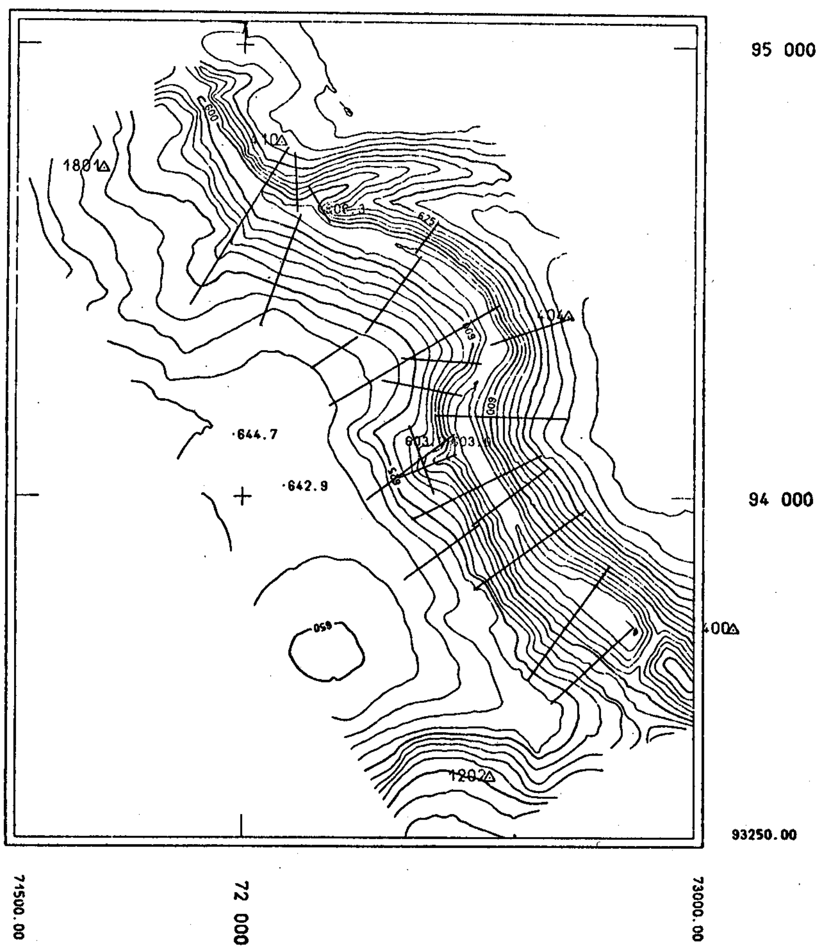

Fig. 6 Test field Söhnstetten with check profiles

Zusammenfassung

Das PLANITOP F2 stellt das kleinste und billigste Auswertegerät der Firma ZEISS mit strenger Lösung dar. Es dient hauptsächlich zur grafischen und digitalen Auswertung von Überweitwinkel- und Weitwinkelbildern im kleinen und mittleren Maßstabsbereich. Am Institut für Photogrammetrie der Universität Stuttgart wurden Untersuchungen über verschiedene Einsatzmöglichkeiten des PLANITOP F2 angestellt. Die Untersuchungen beziehen sich auf Gittermessungen, Einzelmodellauswertungen, Messungen von Aerotriangulationen, Zeichnen und Digitalisieren von Schichtlinien, sowie auf die Messung eines Digitalen Geländemodells. Im vorliegenden Bericht werden die wichtigsten Ergebnisse und Erkenntnisse zusammengestellt und kommentiert.

Abstract

The PLANITOP F2 is the smallest and least expensive stereoplotter of CARL ZEISS, Oberkochen, with a strict solution using mechanical space rods. It has been developed for the use in medium and small scale grafical or numerical plotting of super-wide-angle or wide-angle photography. At the Photogrammetric Institute of Stuttgart University several investigations were performed to test the applicability of the PLANITOP F2 for different tasks. The experimental tests included the measurements of grids, single models, and aerial triangulations, as well as the plotting and digitalization of contour lines, and the measurement of a digital terrain model. In this paper the most important results and conclusions are presented and discussed.

Résumé

Parmi les appareils restituteurs de solution rigoureuse construits par CARL ZEISS, le PLANITOP F2 constitue le modèle le plus petit et le moins onéreux. Il se prête à la restitution graphique et digitale - à petite et à moyenne échelle - de photographies grand-angulaires et super-grand-angulaires. L'institut de Photogrammetrie de l'Université de Stuttgart a entrepris une série d'investigations au sujet des différentes possibilités de mise en oeuvre du PLANITOP F2, à savoir mesures sur réticule, restitution de modèles isolés, mesures de triangulation aérienne, restitution graphique et digitale de courbes de niveau, mesure d'un modèle de terrain digital. L'exposé mentionne et commente les résultats les plus intéressants des investigations, ainsi que les conclusions qui peuvent en être tirées.

Resumen

El PLANITOP F2 corresponde al restituidor de solución rigurosa más pequeño y más económico que ofrece la casa Zeiss. Sirve principalmente para la restitución gráfica y digital de imágenes supergranangulares de escalas pequeñas y medianas. En el Instituto de Fotogrametría de la Universidad de Stuttgart se han estudiado las varias posibilidades de aplicación del PLANITOP F2. Estos estudios se refieren a mediciones de retículas, restituciones de modelos individuales, mediciones de aerotriangulaciones, dibujo y digitalización de curvas de nivel así como mediciones de un modelo digital del terreno. En la presente conferencia se compilan y se comentan los resultados y las conclusiones más importantes.

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