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EXPERIENCE WITH THE ZEISS C-100 PLANICOMP ANALYTICAL STEREOPLOTTING SYSTEM IN TRAINING AND RESEARCH

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1. Introduction

The C-100 ZEISS PLANICOMP System was purchased by Munich Technical University and installed in May 1978. Basic equipment included the optomechanical basic unit, the electronic control unit, an HP 21MXE computer with 64 K words, 15 Mbyte magnetic disk, RTE III operating system and ZEISS software, a graphical VDT with cassettes, a mechanical printer and a DZ-6 Digital Tracing Table. In the meantime, the equipment has been expanded by a second VDT and the new RTE IV operating system, and the memory has been expanded to 128 K words. A magnetic tape deck is expected on loan from the German Research Association by the end of 1979.

In the following, an account will be given of the practical use of the equipment system in teaching, research and development, based on the experience made since mid-1978, and an attempt will be made to judge the C-100 PLANICOMP from a university viewpoint.

2. Practical use in training

The C-100 PLANICOMP is demonstrated to students of surveying, civil engineering and architecture. Practical work on the system is reserved to a "photogrammetric equipment course" for surveying students. In view of the limited time available, however, the students can presently be instructed only in orientation programs and simple user programs.

Much more intensive use of the C-100 will become possible within the framework of a "Photogrammetry and Cartography" course to be offered starting in 1980. In addition to lectures and analytical stereoplotting exercises, this course will also include practical plotting projects.

Intensive work was performed with the C-100 in connection with five diploma theses. Three of these were devoted to the plotting of terrestrial photograms and amateur photography of the Trajan Temple as well as of a Roman aqueduct at Pergamon, Turkey, and a Byzantine basilica at Resafa, Syria. Two theses were devoted to the acquisition of data for digital height models and control work for scanner imagery. Both of them were connected with research and development work that will be discussed in greater detail in the following chapter.

Use of the C-100 in training up to this point has shown that the students do require a certain training period but once this is over are able to use the system largely on their own. The machine is therefore particularly valuable when sufficient time is available. Only then can its full potential be realized and put to practical use. At Munich Technical University, this is possible only within the framework of advanced studies and diploma theses, while basic training only includes demonstration of the principle of analytical stereoplotting and operation of the machine as such.

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3. Practical use in research and development

3.1 Aerial triangulation

As an analytical stereoplotting system, the C-100 PLANICOMP is very well suited for aerial triangulation. This applies, above all, to measurement speed and the possibility of checking the measurement data in the on-line mode |1|. Our studies included the question of whether accuracy would be sufficient to satisfy the high requirements made by advanced block-triangulation techniques.

The test material used was an approximately square block of 51 wide-angle photographs with 60 % end and side lap and signalized control and tie points, which were flown at 1:4000 scale over the Jämijärvi test field by Helsinki Technical University and made available by Prof. Kilpelä, Chairman of Working Group 3 of Commission III of the ISP.

Raw machine coordinates were recorded on the C-100 and then subjected to a bundle block adjustment using the MBOP program written by Dr. Grün. To compensate for systematic image errors, 12 and 44 approximately orthogonal, block-invariant additional parameters were introduced (simultaneous self calibration). From the test results reproduced in detail in |2| and |3|, Table 1 shows a case in which 20 horizontal control points along the edges of the block and 36 spot heights evenly distributed over the block at intervals of at least one base length were used.

Self calibration	σ_o	$\mu_{x,y}$	μ_z
No	4.8µm	3.9µm	6.7µm
Yes	4.1µm	2.6µm	4.5µm
Increase in accuracy	1.2	1.5	1.5

Table 1

Bundle block adjustment with self calibration (44 additional parameters) gave a standard deviation of image coordinates of $\sigma_o = 4.1\mu m$ and an absolute accuracy computed from approx. 100 available check points $\mu_{x,y} = 2.6\mu m$ for horizontal position and $\mu_z = 4.5\mu m$ for elevation (referred to a photo scale of 1:4000). By comparison with bundle block adjustment without compensation of systematic errors, the increase in accuracy for σ_o was 1.2x, that for $\mu_{x,y}$ and μ_z 1.5x.

Since ZEISS PSK-1 measurements were also available for the Jämijärvi test block, an accuracy comparison between C-100 and PSK-1 could be made under similar conditions. This comparison revealed that the results with self calibration shown in Table 1 are only 10 - 20 % less favorable than comparable PSK-1 results.

For practical purposes this means that the C-100 PLANICOMP is a very adequate measuring machine for photogrammetric point determination, even in cases where very high accuracy is required. In this case, the slightly lower accuracy than that of comparators can be offset by the use of a somewhat larger photo scale.

3.2 Stereoplotting of aerial photography

Two model projects were performed in collaboration with the Bavarian Ministry of Agriculture and Forestry, in which the added potential of analytical stereoplotters for the use of photogrammetry in reallotment were to be tested. The first of these projects concerned a new terrestrial photogrammetric technique for determining and surveying the boundaries of roads and water bodies,

making use of the possibility of digital point approach, whereas the second project dealt with the production of slope contour charts and oblique ground representation on the basis of profile and grid data obtained in a C-100. Both these projects will be discussed in a separate paper by Mr. Zippelius |4| so that we need not got into further detail here.

The work involving slope contour charts and oblique ground representation is performed in connection with an extensive software development for digital height models that is presently under way at the Institute of Photogrammetry of Munich Technical University. This provides for the generation of digital height models (DHMs) by a simple variant of the method of finite elements, which in addition to profile data, grid data or contours also makes rigorous allowance for break lines |5|. A further version of the program provides for the computation and plotting of contours from profile or grid data. The program is written in Fortran for the HP 21MX minicomputer of the PLANICOMP.

Up to now, a model of high mountains and one of hilly terrain were digitized in the C-100 for DHM test purposes. Grid-type measurement, in which the operator has sufficient time to place the floating mark on the grid point before triggering xy-travel to the next point by depression of the foot control, proved to be much more convenient than profile measurement. Although the corresponding comparisons of accuracy and economy are not yet available, they will presumably be in favor of grid-type measurement.

3.3 Plotting of terrestrial photograms

Uses of terrestrial photogrammetry in archeology were already mentioned in chapter 2. In addition, test measurements were made for Working Group 2 of Commission II of the ISP, together with plotting work within the framework of a large industrial-photogrammetry project.

The photography plotted included Wild P31 and P32 cameras, ZEISS SMK, JENA UMK, and the old TAF (terrestrial equipment by Finsterwalder). Both with regard to measurement speed and the handling of random photo tilt and calibrated focal length, the C-100 was found to be very useful. However, it was found to be a disadvantage that the software presently available does not allow the compensation of principal-point errors nor rigorous allowance to be made for the known values of individual orientation parameters that are fairly easy to obtain in terrestrial photogrammetry and may support the model to a considerable extent.

3.4 Special uses

Apart from true metric photography, several photographs obtained with 35 mm and Hasselblad cameras as well as underwater photography taken at a depth of approx. 5000 m were plotted. In addition to the aspects mentioned under 3.3, the problem may here be encountered that interior orientation will first have to be reconstructed from calibration measurements and then introduced into the plotting process.

For the general field of terrestrial photogrammetry and special uses it therefore appears desirable to generalize the orientation programs presently available. Dr. Stephani of the Photogrammetric Institute is presently engaged in such development work. This is based on a bundle solution with additional parameters for the photo pair and will be capable of rigorous processing of given orientation parameters.

Another special use of the C-100 PLANICOMP was found in conjunction with the digital rectification of scanner imagery in which exterior orientation of the different lines is recovered with the aid of the relatively large number of control points |6|. If aerial photography is available in addition to the scanner image, the control points can first be obatined by stereoplotting in the C-100. Then, one of the two photos is exchanged for the scanner image and the control points whose image coordinates have previously been stored are digitally approached in the air photo, the point being identified in the

scanner image and its coordinates measured. The coordinates are then numerically retransformed into lines and columns of the corresponding picture elements. The experience available up to date shows that this method is an interesting interim solution until more efficient point-transfer methods based on digital image correlation will become available.

4. Conclusions

Wide use of the instrument system since the middle of 1978 has shown that the overall reliability of the C-100 PLANICOMP is good. This applies both to the basic unit and the computer. A single software error, which was detected during use of the system, was rapidly corrected by ZEISS. The overall system is well-designed, its accuracy and operator comfort are very satisfactory. As far as the DZ-6 Digital Tracing Table is concerned, desirable features would be suitability for off-line and parallel operation with the C-100.

The software is sufficient for standard uses, but should be documented as soon as possible. Naturally, further user programs for the HP 21MX computer appear desirable, above all for the purposes of photo orientation, on-line aerial triangulation, bundle block adjustment with self calibration and digital terrain models. Programs of this type are being developed by several organizations.

Summarizing, we may say that the C-100 PLANICOMP is very suitable for university use as an analytical stereoplotting system. This is due, on the one hand, to its great flexibility which allows the most varied uses and, on the other, the possibility of continually increasing the efficiency of its software - a completely new possibility by comparison with analog equipment.

References

|1| HOBBIE, D.: On-line Aerial Triangulation with the PLANICOMP C-100 Analytical Stereoplotting System. Paper presented to the Symposium of Commission III of ISP, Moscow 1978. Nachrichten aus dem Karten- und Vermessungswesen, Reihe II, Heft 36, 141-149.

|2| EBNER, H.: The Accuracy Potential of the Analytical Plotter ZEISS PLANICOMP C-100 in Bundle Triangulation with Simultaneous Self-Calibration. Volume in honour of Prof. Solaini, on the occasion of his 70th birthday. In press.

|3| EDER, K. and GRÜN, A.: Compensation of Systematic Image Errors with Bundle Block Adjustment using ZEISS PLANICOMP C-100 Data. Paper presented to the Meeting of Working Group III/3 of ISP, Aaalborg / Denmark, 1979.

|4| ZIPPELIUS, K.: Neue Anwendungen analytischer Auswertegeräte in der Flurbereinigung. 37. Photogrammetrische Woche 1979, Vortrag Nr. 10.

|5| EBNER, H. and REISS, P.: Height Interpolation by the Method of Finite Elements. Paper presented to the Symposium of Commission III of ISP, Moscow 1978. Nachrichten aus dem Karten- und Vermessungswesen, Reihe II, Heft 36, 79-94.

|6| HÜSSLER, R.: High Accurate Geometric Rectification - Necessity and Realization. Paper presented to the Symposium of Commission VII of ISP, Freiburg 1978.

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Abstract

The paper gives an account of practical use of the C-100 PLANICOMP at the Institute of Photogrammetry of Munich Technical University since its installation in May of 1978.

The C-100 is demonstrated to students of surveying, civil engineering and architecture. Within the framework of special courses and diploma theses, practical work is performed on the machine. The response of students, especially those working on their theses, has been very positive.

In a series of research projects in which aerial photography, terrestrial photograms, 35 mm and 6 x 6 cm photography as well as scanner imagery were plotted, the overall reliability of the C-100 proved to be good. A controlled block triangulation with 51 wide-angle photos, 60 % side lap and signalized points gave an absolute rms accuracy of 3 µm at the photo scale in x and y and approx. 5 µm in z. Dense control was available, and bundle adjustment was of the self-calibrating type.

The PLANICOMP software is sufficient for standard uses, but certain expansions appear desirable. Special programs for image orientation and the generation of digital height models are being developed in Munich.

In view of its high flexibility and accuracy and the possibility of further increasing its efficiency through suitable software, the C-100 PLANICOMP is ideal for training applications.

Erfahrungen mit dem analytischen Stereoauswertesystem ZEISS PLANICOMP C-100 in Lehre und Forschung

Zusammenfassung

Der Beitrag gibt einen Überblick über den praktischen Einsatz des PLANICOMP C-100 am Lehrstuhl für Photogrammetrie der TU München seit der Installation im Mai 1978.

In der Lehre wird der C-100 den Studierenden des Vermessungswesens, des Bauingenieurwesens und der Architektur vorgeführt. Im Rahmen der Vertiefung und von Diplomarbeiten wird praktisch am Gerät gearbeitet. Die Reaktion der Studierenden, insbesondere der Diplomanten, ist sehr positiv.

Bei einer Reihe von Forschungsprojekten mit Auswertungen von Luftaufnahmen, terrestrischen Meßbildern, Kleinbild- bzw. 6 x 6-Aufnahmen und Scannerbildern hat sich der C-100 insgesamt als zuverlässig erwiesen. Eine kontrollierte Blocktriangulation mit 51 Weitwinkelaufnahmen, 60 % Querüberdeckung und signalisierten Punkten hat bei dichter Paßpunktverteilung und Bündelausgleichung mit Selbstkalibrierung eine mittlere Absolutgenauigkeit von ca. 3 µm im Bildmaßstab in x,y und von ca. 5 µm in z ergeben.

Die Software reicht für die Standardanwendungen aus, gewisse Erweiterungen erscheinen aber als wünschenswert. Eigene Programmentwicklungen sind in München auf dem Gebiet der Bild-Orientierung und des Digitalen Höhen-Modells in Bearbeitung.

Durch die hohe Flexibilität und Genauigkeit und durch die Möglichkeit, die Leistungsfähigkeit über Software noch weiter zu steigern, ist der PLANICOMP C-100 ein ideales Gerät für den Einsatz an Hochschulen.

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Expériences avec le système de stéréorestitution analytique ZEISS PLANICOMP C-100 dans la recherche et dans l'enseignement

Résumé

L'article donne un aperçu de l'application pratique du PLANICOMP C-100 à la Chaire de Photogrammétrie de l'Université Technique de Munich depuis l'installation en mai 1978.

Dans l'enseignement le C-100 est présenté aux étudiants de technique de mensuration, d'architecture et de génie civil. Dans le cadre de l'approfondissement et des travaux de diplôme on travaille en pratique avec l'appareil. La réaction des étudiants, sûrtout de ceux qui préparent leur diplome est très positive.

Dans une série de projets de recherche avec analyse de levés d'amateurs, d'images du scanner, de vues terrestres et aériennes le C-100 s'est montré dans son ensemble sur. Une triangulation de bloc controllée avec 51 vues grand - angulairs, 60 % recouvrement transversal et des points signalés a eu, par distribution dense de points de contrôle et par restitution par faisceaux avec l'autoétalonnage, une précision absolue moyenne d'environ 3 µm en échelle de l'image en x et y et d'environ 5 µm en z.

Le software suffit pour les applications standard, mais certains élargissements s'avèrent désirables. Des programmes propres dans le domaine d'orientation des modèles et du modèle digital de hauteur sont en préparation à Munich.

Par sa grande flexibilité et sa haute précision et par la possibilité d'améliorer les capacités par le software, le PLANICOM C-100 est un appareil idéal pour l'application dans les universités.

Experiencias adquiridas durante la utilización práctica de restituidores analíticos en investigación y enseñanza

Resumen

La conferencia da una vista de conjunto del empleo práctico del PLANICOMP C-100 en la cátedra de fotogrametría de la Universidad Técnica de Munich, desde su instalación en el mes da mayo de 1978.

El instrumento sirve para la enseñanza a los estudiantes de agrimensura, de ingeniería civil y de arquitectura. Para una mayor especialización y para obtener diplomas se efectúan trabajos prácticos en el instrumento. La reacción de los estudiantes, y especialmente de los diplomados, es muy positiva.

El C-100 se ha manifestado como muy fiable en una serie de proyectos de investigación con restituciones de fotos tomadas por aficionados, fotos de explorador, fotogramas terrestres y aéreas. Una triangulación de bloque controlada con 51 fotos gran angulares, recubrimiento transversal de un 60 % y puntos señalizados ha dado, para una distribución densa de puntos de apoyo y compensación de haces con autocalibración, una exactitud absoluta media de aprox. 3 µm a la escala de la imagen en x, y y de aprox. 5 µm en z.

El software es suficiente para aplicaciones normales, pero aparecen deseables ciertas ampliaciones. La Universidad de Munich está preparando sus propios programas para la orientación de modelos y los modelos altimétricos digitales.

Por su alta flexibilidad y por la posibilidad de aumentar aún más su eficacia mediante software, el PLANICOMP C-100 es un instrumento ideal para el empleo en la enseñanza superior.

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