

THE PROGRAM SYSTEM FOR THE ZEISS Z-2 ORTHOCOMP

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Summary

The Z-2 ORTHOCOMP is an analytical ortho projector which is controlled by an HP 1000 mini computer. With this paper a brief description is given of the program system developed for the Z-2. The main programs are SCAN (for differential first order rectification on secants), PRINT (for exposure of symbols on the ortho photo film), ORIENT (for interior and absolute orientation of the photograph to be rectified), and PARAM (for input of the various parameters). The program system further contains support programs for preparation of parameters, editing of data, measurement of the density of the photograph, and for listing a log with the rectification parameters.

One important feature of these programs is the fact that terrain or model coordinates are used as input, i.e. data which are not restricted to a single photograph. The data can be used to rectify any suitable photograph of the respective terrain area. A second important feature of the software is the adaptability to various tasks regarding the photo geometry, the orientation procedure and the profile configuration. In addition to the standard software the optional HIFI-P program (H. EBNER et al.) provides a means to compute control profiles from terrain elevation data of almost any arbitrary distribution.

The basic concept

In figure 1 the hardware components of the Z-2 ORTHOCOMP are shown. The hardware comprises the projector with the optical and mechanical elements, the control electronics in a separate housing, and the HP 1000 mini computer which usually is equipped with a magnetic tape drive and a printer. The ortho projector is designed to produce photographic rectifications, i.e. ortho photos, by differential first-order rectification of aerial or terrestrial photographs. The rectification is achieved by optical means which are controlled by the computer via the control electronics and servo drives. The optical and mechanical components are shown very simplified in the lower part of figure 2. The film to be exposed is held on a film drum. It is exposed successively strip by strip through a slit aperture. The photograph to be rectified is placed on a photo carriage which moves in X and Y direction and which is imaged on the slit aperture via a zoom lens of variable magnification and a Dove prism for image rotation. Slit and drum position, photo position, magnification, and image rotation are controlled by the computer.

For rectification of a photograph informations are needed on the terrain elevations and on the camera orientation with which the photograph was taken. The elevation data are needed as parallel profiles in terrain coordinates or in a levelled model coordinate system. In figure 2 the various coordinate transformations are sketched which are applied to the profile data. The coordinate system of the primary profiles is called the "Data System". This Data System is related to the Terrain System by a plane similarity transformation computed from the coordinates of at least three control points. From the Data System a "Profile System" is derived in which the Y-axis is parallel to the profile direction. The transformation from the Data System to the Profile System is computed in several steps including interpolation of new profiles. The result is a set of profiles in the ortho photo scale, all having the same distance to each other which corresponds exactly to the length of the slit aperture chosen for rectification. The "Film System" simply is the X/Y plane of the Profile System. On the other side a "Model System" is derived from the Profile System by shifting and rotating so that the origin corresponds to the nadir point of the photograph and the X direction is parallel to the flight line. Finally a central projection is applied to transform the profile lines from the Model System to the photograph. During exposure of an ortho photo strip for each position of the film drum the photo carriage position, the zoom magnification and the image rotation is computed from the photo profile coordinates.

With regard to figure 2 it should be mentioned that for transformation from the Data System to the Profile System not the profiles are rotated, but the coordinate system. The direction of the profiles with respect to the terrain remains unchanged and the direction of the ortho photo strips is parallel to the direction of the primary profiles.

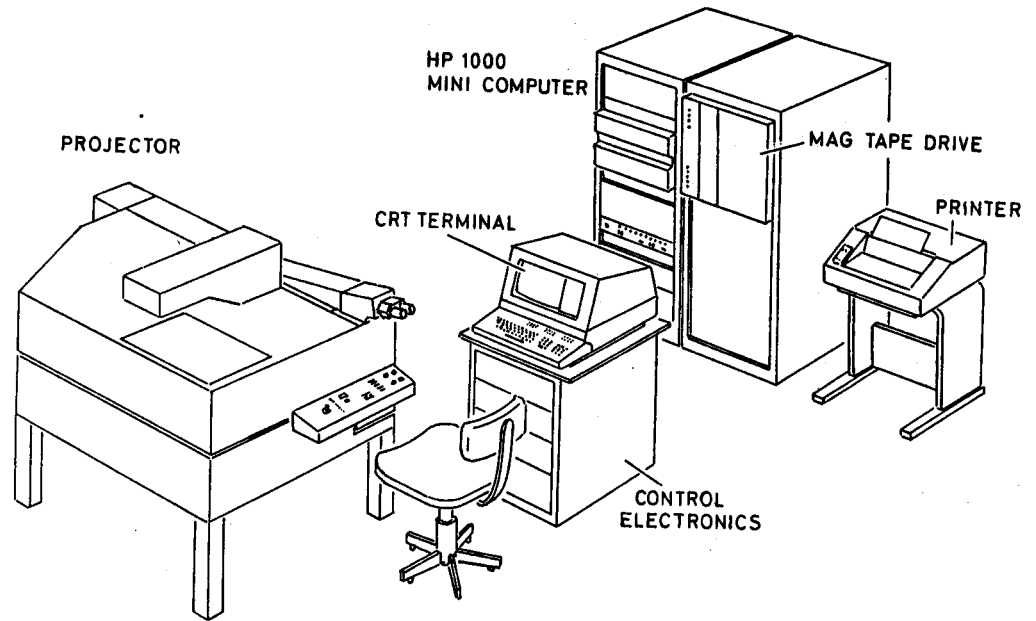


Fig. 1: Hardware components of the Z-2 ORTHOCOMP

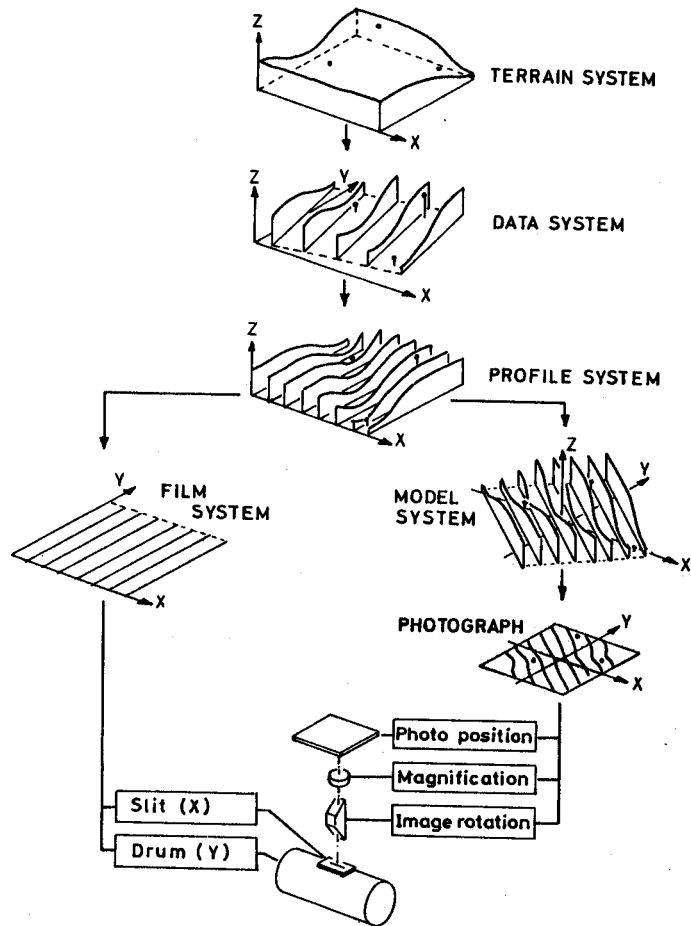


Fig. 2: Coordinate transformations as applied to profile mass data and control points.

The program system

Figure 3 shows a block diagram of the basic program package for the ORTHOCOMP Z-2. The interrelations between the programs are indicated by arrows. The main programs are PARAM for parameter input, ORIENT for determination of the interior and absolute orientation of the photograph, SCAN for exposure of the ortho photo as a first-order rectification on secants, and PRINT for printing symbols or marginal text on the ortho photo film. The use of these main programs is supported by the programs PREPA for parameter preparation, GEFIL for editing control point data or profile data, SNUFI for analyzing profile data, DENSITY for measurement of the optical density in the photograph, and LIST for printing a standard log of each ortho photo exposure.

From the designer's point of view doubtlessly SCAN is the main program. Herein an assembler programmed loop controls the positions of film drum, photo carriage, Dove prism, zoom and illumination lenses to provide the desired rectification as outlined in the previous chapter. Before this loop is started for the first strip, a loop cycle time is computed depending on the chosen drum speed, the ortho photo length, and the mean magnification. From the available cycle times 10, 20, 40, or 80 milli seconds the program selects the smallest for which

- a) the number of loop cycles per strip is less than 1250,
- b) the number of 1-micron steps of the photo carriage is at least 512, but less than 1023 per loop cycle, or
- c) the number of 2.5-micron steps of the film drum is at least 200 per loop cycle.

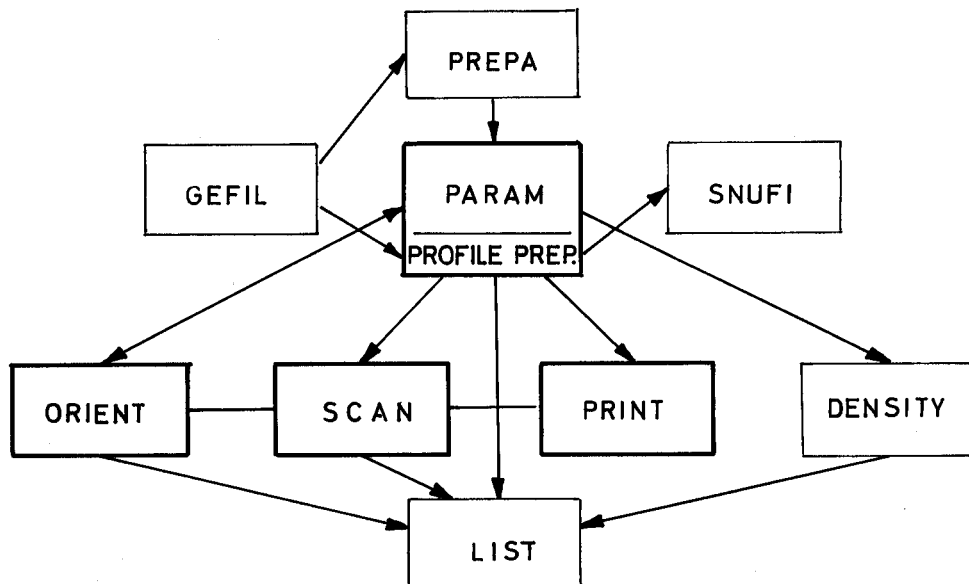


Fig. 3: The basic programs for the ORTHOCOMP Z-2 and their interrelations.

Then for each ortho photo strip control profiles with a distance corresponding to the chosen slit size are interpolated from the primary profiles. These linearly interpolated control profiles have constant point distance equal to the drum movement for one loop cycle. Typically the point distances range from 0.5 mm to 1.2 mm.

From the operator's point of view, SCAN is the simplest of all the programs. Before starting the program, the operator loads the film and sets at the control panel the knobs for drum speed (5, 10, 20, 30, 40, or 50 mm/s), for slit size (2, 4, 8, or 16 mm in standard equipment) and for the light level. These settings are displayed on the terminal screen for checking. When the settings have been confirmed by the operator the program produces the ortho photo automatically without any assistance from the operator. Typical scanning times range from 11 minutes for an ortho photo 400 x 400 mm² scanned with 50 mm/s and 8 mm slit to 48 minutes for an ortho photo 770 x 770 mm², scanned with 40 mm/s and 8 mm slit.

For the operator of the ORTHOCOMP the main program is PARAM for input of all the essential ortho photo parameters (ortho photo scale, photo orientation data or control point coordinates to determine the photo orientation, focal length and

fiducial distances of the camera with which the photo was taken, kind of photograph - negative or positive - and kind of ortho photo - normal or reversed -, coordinates of map sheet corners, desired run-over beyond these sheet corners, position of the ortho photo on the film via the start coordinates), and also for input of less essential parameters used for checks and documentation (film type and size, map sheet name, operator's name etc.). Depending on the individual task, between 50 and 124 ortho photo parameters have to be checked or input. The handling of the parameters is facilitated by three provisions:

- a) The program is a dialogue program which asks for each parameter. Thus no parameter can be omitted.
- b) For each parameter the last input is presented as default value at the terminal screen. If this default value is accepted, only the RETURN key has to be pressed.
- c) Most of the parameters are presented in groups and the complete group can be accepted by pressing the RETURN key once. By this provision, the complete list of parameters can be confirmed with ten times pressing the RETURN key. So, correction of one single parameter is not time consuming.

A further facility is provided by the program PREPA. With this program part of the ortho photo parameters can be prepared on a second terminal or even on another HP 1000 computer. The readily prepared parameters then are transferred to the ORTHOCOMP via disc file or magnetic tape. The program PREPA handles parameters which are related to the profiles (profile number, control point coordinates in the Data System etc) and parameters which are related to the terrain (terrain control points for orientation and for relating the Data System to the terrain coordinate system, map sheet corners etc.). These are parameters which usually remain unchanged when a map revision is made by rectifying new photography. For that reason these profile- and terrain-related parameters can be stored separately and filed for later use in archives together with the profile data sets.

The profile data, typically some 2000 to 20000 point records stored on disc file or magnetic tape, are read into the computer memory in the last step of the parameter program. The shift and rotation of the coordinate system (see previous chapter) is carried out in this step. The program accepts profiles with varying distances, and it accepts also varying distances of the points within the profiles. Each point record is checked whether the point belongs to the actual profile, or presents the first point of a new profile. The transformed profiles are stored on a disc file. In case of error messages the operator can use the program SNUFI to analyze the profile data on that file. Unsuitable profiles can be skipped by a parameter set by the operator.

After the program PARAM usually the program ORIENT is run. The program has two sections. In the first section - the interior orientation - the position of the photograph on the photo carriage and the position of the principal point of the photograph are determined. The procedure is to set a floating mark on the fiducial marks of the photograph. Photograph and floating mark are viewed through a binocular eyepiece. The program automatically positions the photo carriage to the places where the fiducials of the last photograph have been. Usually this is quite near to the fiducial of the new photograph. For the exact positioning the operator moves the photo carriage via a joy stick.

Whereas the interior orientation program must be run for each new photograph, the use of the second part of the ORIENT program - for absolute orientation - is not a must. Provided the absolute orientation parameters (X, Y, Z of the projection center and the tilts φ, ω, κ) are known and were entered during the PARAM program, the absolute orientation program may be skipped. However, the program can likewise be used to check the orientation parameters which have been entered, or to determine these parameters if they are not known. The absolute orientation is computed iteratively as a space resection using terrain coordinates X, Y, Z of at least three control points and the respective photo coordinates x, y . For determination of the photo coordinates the operator positions the floating mark on the control point images in the photograph. This procedure is supported by program-controlled repositioning of each control point after the second if the absolute orientation parameters were not known. On the other hand, if the absolute orientation parameters were entered during the PARAM program, the photo carriage drives automatically to each control point (including the first and second) and this repositioning may be used as a check of the parameters.

The last of the main programs is PRINT. With this program symbols or text lines can be exposed on the ortho photo film. For that purpose the photo carriage is provided with a symbol matrix the symbols of which can be imaged on the film. The standard matrix is composed of the 26 capital letters, the 10 numerals and 13 additional symbols. For printing a text line the operator uses the corresponding keys of the terminal keyboard to enter the text. Then the program asks for the position of the first symbol (to enter either as terrain coordinates X,Y or as film coordinates), for the angle of the text line relative to the X axis of the chosen coordinate system, and for the size of the symbols. When these inputs are completed the program positions the Dove prism and the zoom corresponding to the desired line angle and symbol size. Then the text symbols are printed one after the other with program controlled positioning of photo carriage, film drum and slit carriage (on which a circular aperture is used in place of the slit aperture used for SCAN). The program automatically prints true-to-side or side-reversed symbols depending on the nature of the ortho photo (positive or negative, normal or reversed). The map sheet corners can be marked by suitable symbols (for example crosses) without repeating the coordinate's input (the coordinates as input in the PARAM program are used). The PRINT program is applied quite extensively by the users of the ORTHOCOMP Z-2. It represents not only a means to note marginal informations on the ortho photo film, but also a means for quite critical tests of the instrument's performance and the input data quality.

The DENSITY program is used to measure the optical density at different positions of the photograph. The knowledge of the density as measured with the ORTHOCOMP illumination may be of interest since it differs from measurements in the usual densitometers with diffuse illumination (Callier effect). The DENSITY program itself is very simple. It asks the operator to position the photo carriage to the photo spot of interest. When the operator presses a button at the ORTHOCOMP panel, the program transfers the density value to the calculator memory. At the end of the program the maximum and the minimum of the measured density values is displayed as well as the mean density computed from all the measured spots. These results are also stored on a disc file for listing in the log which is produced by the program LIST.

The LIST program prints a standard log with 50 ortho photo parameters, beginning with the map sheet name and scale and ending with the number of strips and the time needed to scan the ortho photo. The list includes also the result of the plane similarity transformation from the profile data coordinate system to the terrain system (if applicable), the results of the orientation, and the results of the density measurements.

Conclusion

The program system for the ORTHOCOMP Z-2 was designed by D. HOBBIE. The programming was carried out by J. SUCHANEK and by H. SPRONGL. The author's part was the testing of the programs.

Not described in this paper are the HIFI programs developed by H. EBNER (Munich) and his co-workers. These programs extend the field of applications of the ORTHOCOMP Z-2 considerably. HIFI-P derives parallel control profiles from arbitrary point distributions. HIFI-PC derives contour lines from the regular digital terrain model computed by HIFI-P, HIFI-PS derives control profiles for the production of stereo ortho photos.

Das Programmsystem des Zeiss ORTHOCOMP Z-2

Zusammenfassung

Der ORTHOCOMP Z-2 ist ein analytischer Orthoprojektor, der von einem Mini-Computer HP 1000 gesteuert wird. Die Hauptprogramme sind die Belichtungs-Programme SCAN (Entzerrung 1. Ordnung auf Sekanten) und PRINT (Einbelichtung von Symbolen), sowie die Programme ORIENT (Orientierung des Bildes) und PARAM (Parametereingabe). Dazu kommen Hilfsprogramme für Parameter-Vorbereitung, File-Editieren, Profil-Analyse, Schwärzungsmessung und Protokoll-Ausgabe.

Ein wesentliches Merkmal dieser Programme ist, daß als Eingangsdaten Gelände- oder Modellkoordinaten verwendet werden, die sich nicht auf ein spezielles Bild beziehen, sondern für jedes Bild des betreffenden Geländeausschnittes gültig sind.

Ein zweites wichtiges Merkmal der Programme ist die Anpassungsfähigkeit an unterschiedliche Aufgabenstellungen, erreicht durch geringe system-bedingte Restriktionen bezüglich Bildart, Art der Orientierung, Profil-Konfiguration und Orthophoto. Zusätzlich bietet das Programm HIFI-P (H. EBNER und Mitarbeiter) die Möglichkeit, Steuerprofile aus nahezu beliebigen Höheninformationen abzuleiten.

Les programmes de l'ORTHOCOMP Z-2 de Zeiss

Résumé

L'ORTHOCOMP Z-2 est un orthoprojecteur analytique commandé par un miniordinateur HP 1000. Les programmes principaux sont les programmes d'exposition SCAN (redressement de 1er ordre sur des sécantes) et PRINT (exposition de symboles) ainsi que les programmes ORIENT (orientation du cliché) et PARAM (entrée de paramètres). A cela s'ajoutent les programmes auxiliaires concernant la préparation des paramètres, le File Edit, l'analyse des profils, la mesure de la densité du cliché et la sortie de la liste de contrôle.

Un caractère essentiel de ces programmes: on utilise comme données d'entrée des coordonnées-terrain ou des coordonnées-modèle qui ne se réfèrent pas à une image précise mais qui sont valables pour chaque image du secteur du terrain concerné. Deuxième caractère essentiel de ces programmes: leur adaptabilité à différentes tâches qui est réalisée par un minimum de restrictions relatives au type de l'image, à la façon de l'orientation, à la configuration du profil et à l'orthophoto. Le programme HIFI-P (H. EBNER et ses collaborateurs) permet en plus de dériver des profils de commande de presque toutes les informations altimétriques.

El sistema de programas del Zeiss ORTHOCOMP Z-2

Resumen

El ORTHOCOMP Z-2 es un ortoprojector analítico mandado por un minicomputador HP 1000. Los programas principales son: los programas de exposición SCAN (rectificación de primer orden a secantes) y PRINT (exposición de símbolos) así como los programas ORIENT (orientación de la imagen) y PARAM (entrada de parámetros). A ello se añaden programas auxiliares para preparar los parámetros, la edición de ficheros, el análisis de perfiles, la medición de densidades y la salida de protocolos.

La característica principal de estos programas es la que en calidad de datos de entrada pueden utilizarse coordenadas terreno o modelo que no se refieren a determinada imagen sino que son válidas para cada imagen del sector del terreno en cuestión. Otro rasgo importante de los programas es su adaptabilidad a problemas diversos, lo que se ha conseguido gracias al reducido número de restricciones inherentes al sistema, relativas al tipo de la imagen, índole de la orientación, configuración de los perfiles y ortofoto. Además, el programa HIFI-P (H. EBNER y colaboradores) brinda la posibilidad de derivar perfiles de mando de informaciones altimétricas casi discrecionales.

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