

THE ZEISS STEREOCORD FOR MANIFOLD MEASURING AND
 INTERPRETATION APPLICATIONS
 Reiner Schwebel, Oberkochen
 Hans Mohl, Stuttgart
 Carl Zeiss, Oberkochen
 Fachhochschule für Technik, Stuttgart
 West Germany
 Commission VII

1. Introduction

The G3 Stereocord is a simple analytical plotting system for numerical and graphical plotting in photo interpretation and photogrammetry. The G3 version and its basic functions were presented in 1981 by H. Mohl /1/. In the meantime, this version has been expanded into a system tailored mainly to graphical applications by means of new hardware and software components. In view of the wide range of applications of the G3, the development work was done by experts of different fields¹⁾ in exemplary cooperation. The G3 design concept enables the user to configure the software in accordance with his specific requirements. Thus the G3 Stereocord can truly be called a universally applicable plotting system.

2. G3 Hardware

The G3 Stereocord consists of the following hardware components:

- Opto-mechanical viewer for viewing and measuring stereo pairs
- Direc 2 counter and interface unit
- Hewlett-Packard HP 85 or HP 86 desktop computer (Fig. 1)

The opto-mechanical viewer with x' , y' and px components for measuring the coordinates of the left photo or the x parallax can be extended by a py component for measuring the y parallax. This version of the Stereocord can be used as a computer-supported stereo comparator.

The HP 86 computer is a high-performance personal computer which, for use with the G3, is equipped with 64 KB main memory, a 12" graphics CRT unit, a 5 1/4" floppy disk drive with a capacity of 270 KB, a matrix graphics printer with a printing rate of 80 characters per second and an HP IB interface. This computer can be programmed in BASIC and has a considerable growth potential. Fast access to one or several floppy disk drives speeds up processing in particular during graphical plotting. The HP 9872 C (DIN A3), HP 7580 (DIN A1) or HP 7585 (DIN A0) plotters can be used for graphical output. The high operating speed of the plotters and the choice of up to 8 different tracing tools effectively support the plotting-oriented graphical software.

1) Project management: Dipl.-Phys. H.-W. Faust, Carl Zeiss, Oberkochen
 Prof. Dr. H. Mohl, Fachhochschule für Technik,
 Stuttgart
 Graphical programs: Prof. Dr. E. Jordan, Geograph. Institut TU
 Hannover
 Dipl.-Ing. W. Kresse, Bonn

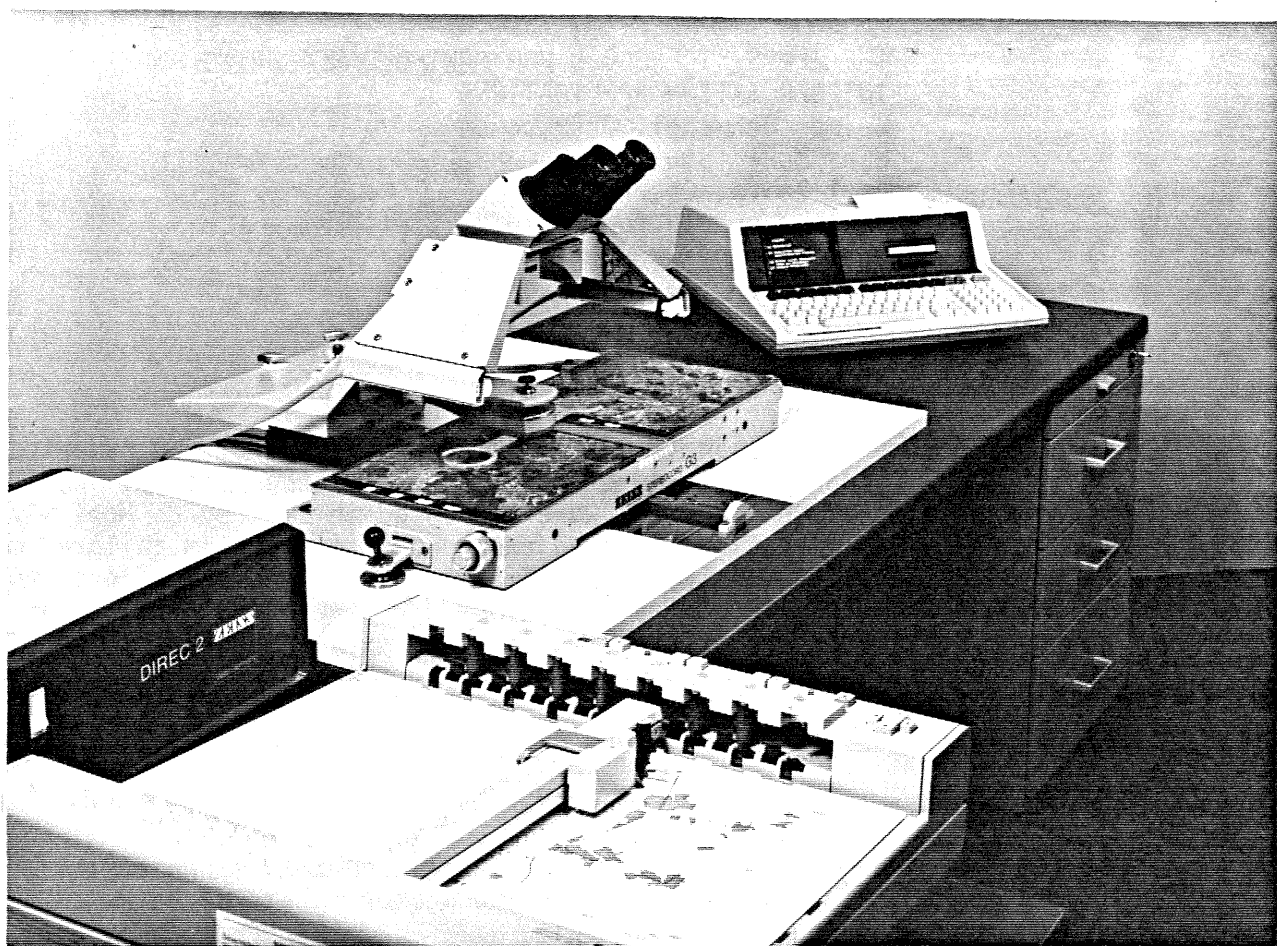


Fig. 1: G3 Stereocord Hardware

The viewer and the Direc 2 of the prior G2 Stereocord version can be upgraded for connection to the HP 85 or HP 86 and for processing the new software.

3. G3 Basic Software

The basic software of the G3 is shown in Fig. 2. It comprises programs for interior, relative and absolute orientation and programs for measuring single points, distances, angles, areas and volumes. Detailed descriptions are contained in /1/ and /2/.

The orientation programs are based on an improved rigorous mathematical model that ensures sufficient precision in keeping with the instrument precision not only in planimetry (20 to 30 μm at the photo scale) but also in elevation (0.2 % of flying height) provided the quality of the photos and the control points is adequate (see section 7.2). If the fourth component (py) is also digitized, orientation is speeded up considerably.

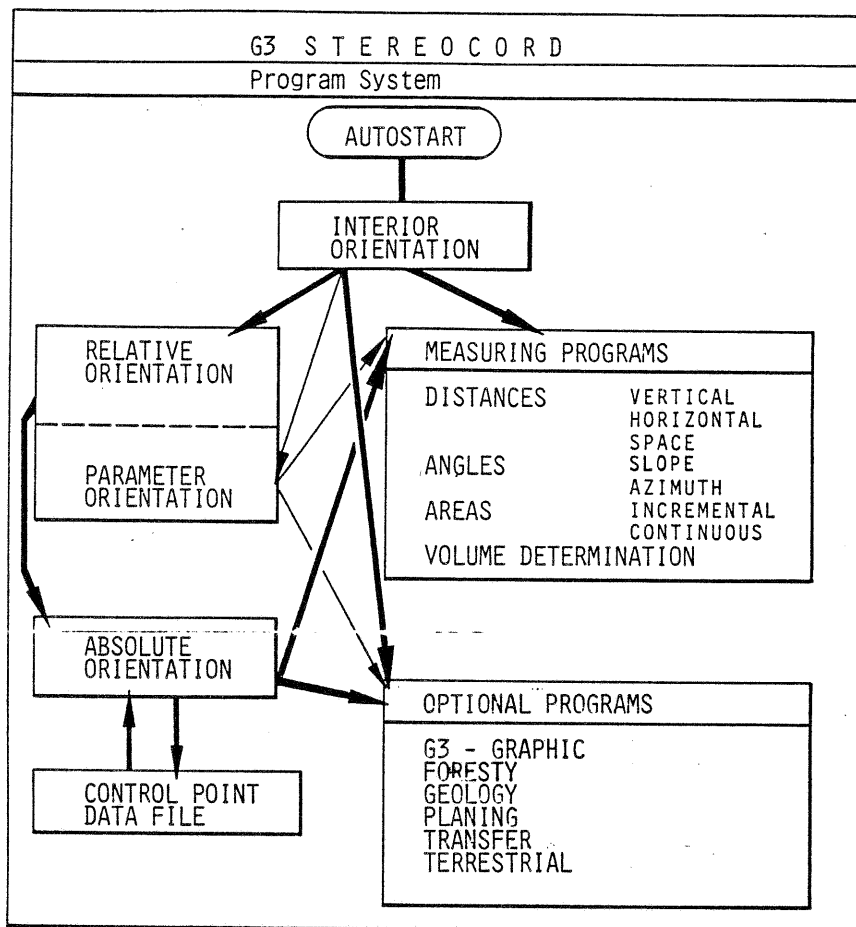


Fig. 2: G3 Stereocord Software Survey

Regarding the orientation programs, the following features may be mentioned:

- Photos of any frame size up to 23 cm x 23 cm.
- Random fiducial mark arrangement and focal lengths and virtually unrestricted taking configurations.
- 6 to 25 points for relative orientation and 3 to 15 points for absolute orientation.
- The control points can be read from a control point memory with a maximum capacity of about 65 points; points can be edited, deleted, modified and added.
- Parameter orientation, reading of parameters used in prior orientation operations, and measurement of the fiducial marks.

After orientation, the above variables are measured, displayed, printed and stored in data files. About 5000 variable values can be stored on a separate cartridge or floppy disk. XYZ ground coordinates are used to compute variables like angles, areas or volumes. A common characteristic of the orientation and measurement programs and of the graphical software described below is operator guidance by means of menus. Explanations, instructions, results as well as correction and selection possibilities are displayed on the CRT screen (Fig. 3). The soft keys of the computer are used for menu selection.

```

*****
S T E R E O C O R D           H P 85 S T E R E O C O R D           H P 85
MEASUREMENT PROGRAMS          VOLUME (PROFILING STEPWISE)
-----
? k1 REAL-TIME-DISPLAY          k1 PROFILE DIRECTION          OK
? k2 DISTANCES / ANGLES        * k2 FIRST PROFILE
? k3 AREAS                      k3 NEXT PROFILE
? k4 VOLUMES                    k4 R E S U L T
? k5 AEROTRIANGULATION         k5 REFERENCE HEIGHT          OK
k6 CHOICE OF PROGRAMS (>>)    k6 REPEAT LAST PROFILE
k7 DIREC 2:REFERENCE-TEST      C k7 CHOICE OF RECORD MODE    P
k8 PARAMETER-LIST              k8 BACK TO OTHER PROGRAMS

```

Fig. 3: G3 Operator Guidance Menus (Example: Volume Determination)

The comprehensive capabilities of the Stereocord software are thus made available to users who are not familiar with photogrammetry in a simple way. Users who intend to develop their own application programs can use the BOSS program to integrate these programs in the G3 software. The basic programs and specific application programs (see section 5) were developed by H. Mohl.

4. G3-GRAPHIC

The basic programs and the application programs described in section 5 are provided for quantitative photo interpretation tasks. Since numerical result representation is insufficient in many cases in particular in the earth sciences, a universal software package was conceived in response to a proposal made by E. Jordan and implemented for the G3 Stereocord by W. Kresse in close cooperation with E. Jordan and Zeiss /3/. This optional software package was called G3-GRAPHIC and has been used by the Geographical Institute of the Technical University of Hannover since 1982. Several projects have been processed successfully (geomorphology, glaciology, see /4/). The HP plotters mentioned in section 2 were used for mapping.

The G3-GRAPHIC software implements computer-supported direct mapping. This means that the operator selectively measures points, lines and areas for automatic on-line plotting with the connected plotter in a predefined graphical representation, i: e. the graphical information is not stored permanently as in digital mapping (see /5/). The salient features of G3-GRAPHIC are its flexibility and user-friendliness. The user can define and edit the desired graphical representation in a preparation phase and have it plotted automatically by the computer in the execution phase. There are limits to the mapping system, of course, due to the use of a relatively small computer.

G3-GRAPHIC comprises the programs shown in Fig. 4. By their functions, these programs can be assigned to three groups as follows:

1. SYMBOL program for digitizing symbol patterns and for symbol management.
2. MAP and TEXT for map preparation, lettering and legends.
3. LINE, AREA and PROFIL for plotting the map content.

The individual programs are called and controlled by the DRAW program. During normal project processing, the SYMBOL program is called first.

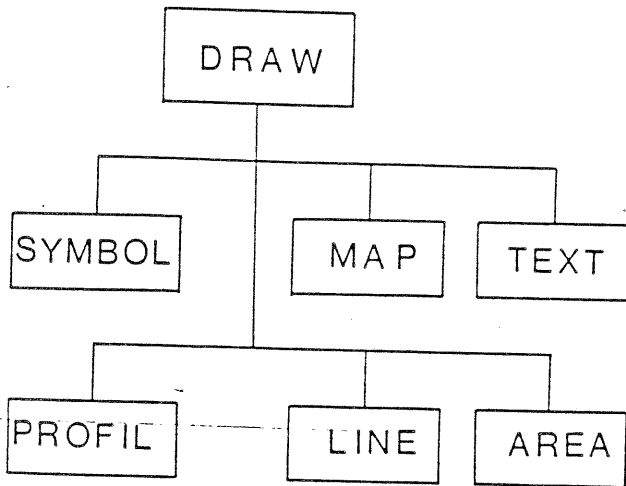


Fig. 4: G3-GRAPHIC Survey

SYMBOL can digitize and manage up to 200 symbols and consists of the SYMGEN and SYMWRK segments. SYMGEN controls digitization of the symbol pattern, which is placed on the Stereocord photo carriage instead of a photo. Straight lines, arcs and circles can be digitized. The symbols are assigned a number and a designation and stored in the symbol file (tape, cartridge). Stored symbols can be displayed on the screen, edited (deletion, rotation, sequence modification) and be used again for other projects (see Fig. 5). The SYMWRK segment was developed in response to experience gained during practical work. It allows 100 "work symbols" to be defined and managed. Not only the symbol type but also the size, rotation, spacing along lines and area distribution can be specified and stored as a work symbol under one number. During model plotting, 10 work symbols are loaded in the computer main memory for fast and easy access. The MAP program is then called for map sheet preparation. It enables map frame and grid plotting, specifying the scale and the plotting window and, if desired, map sheet orientation for subsequent air photo plotting. The TEXT program serves to enter symbols and their explanations in the map legend and for lettering with names etc. with optional character size, slant and rotation (see Fig. 6).

SYMB.-NO.			SYMB.-NO.		
∅		Triangle	10		Cliff
1		Circle	11		Dam
2		TP	12		Wall
3		Church	13		Fence
4		Chapel	14		Electric power line
5		Tower	15		Conif. tree
6		Monument	16		Decid. tree
7		Arrow	17		Heath
8		Bridge	18		Bog, swamp
9		Mine	19		Meadow

Fig. 5: Symbol Representation on the Graphics CRT

When the preparatory work is completed, the content of the oriented model can be plotted. The LINE program serves to digitize linear structures like roads, rivers or break lines and to plot them with the selected work symbols. Digitization is automatic by time increments or selective by foot switch depression. LINE also allows points and elevations to be plotted with optional symbols and characters.

The AREA program serves to map plane structures like lakes, stands, buildings etc. The area is measured as a closed traverse and can be hatched or filled with symbols. So-called islands can be kept clear, and boundary lines can be plotted or omitted. Mapping and area computation can be combined. Finally, the third mapping program called PROFIL enables elevation plotting along a line with independent planimetric and elevation scales.

The many application possibilities are documented in /6/. Sample applications of the G3-GRAPHIC software package are described in section 7.

5. Optional Application Software for Photo Interpretation

The following optional application programs are available in addition to the basic programs and G3-GRAPHIC:

- (a) FORESTRY Program
for forestry investigations, computing tree heights and crown areas, counting, and statistical analysis.
- (b) GEOLOGY Program
for measuring slope angles, strike and dip angles of rock strata, and statistical analysis.
- (c) PLANNING Program
for planning work inclusive of measuring and adding up individual areas, profiles, counting of objects, and statistical analysis.
- (d) TRANSFER Program
for transferring data files between the HP 85/86 and an HP 1000 computer via the HP IB interface. TRANSFER has to be loaded in the desktop computer and in the minicomputer. It allows measured data to be transferred from the Stereocord to a general file of the HP 1000 for further processing with PAT M or HIFI, for example, or control point data to be transferred from the HP 1000 to the control point file of the Stereocord.

6. Optional Software for Terrestrial Photogrammetry

Photos taken in differing configurations with cameras differing in format and focal lengths can be processed with the basic software. Determining the interior orientation by measuring frame edge points is possible. The G3-TERRESTRIAL program package was designed to meet the specific requirements of terrestrial photogrammetry. It comprises the following enhancements of the basic software:

- Interior Orientation: Measurement of 4 or 6 fiducial marks, distortion correction and compensation of changed interior orientation data for cameras which can be focused.
- Absolute Orientation: Use of additional control elements such as distances, direction, planes and exterior orientation components. Weighting of the control elements.
Orientation of photos with strongly divergent taking directions.

Plotting: Plotting in plan, elevation and side elevation. The plotting planes are located in the planes of the coordinate system used.

7. Applications

As described in /7/ on quantitative photo interpretation, the Stereocord has been designed for a very wide field of applications. The G3 version with its precision increase opens up the medium-precision photogrammetric plotting field, and G3-GRAPHIC opens up further photo interpretation fields. Therefore, only some examples can be given in the following.

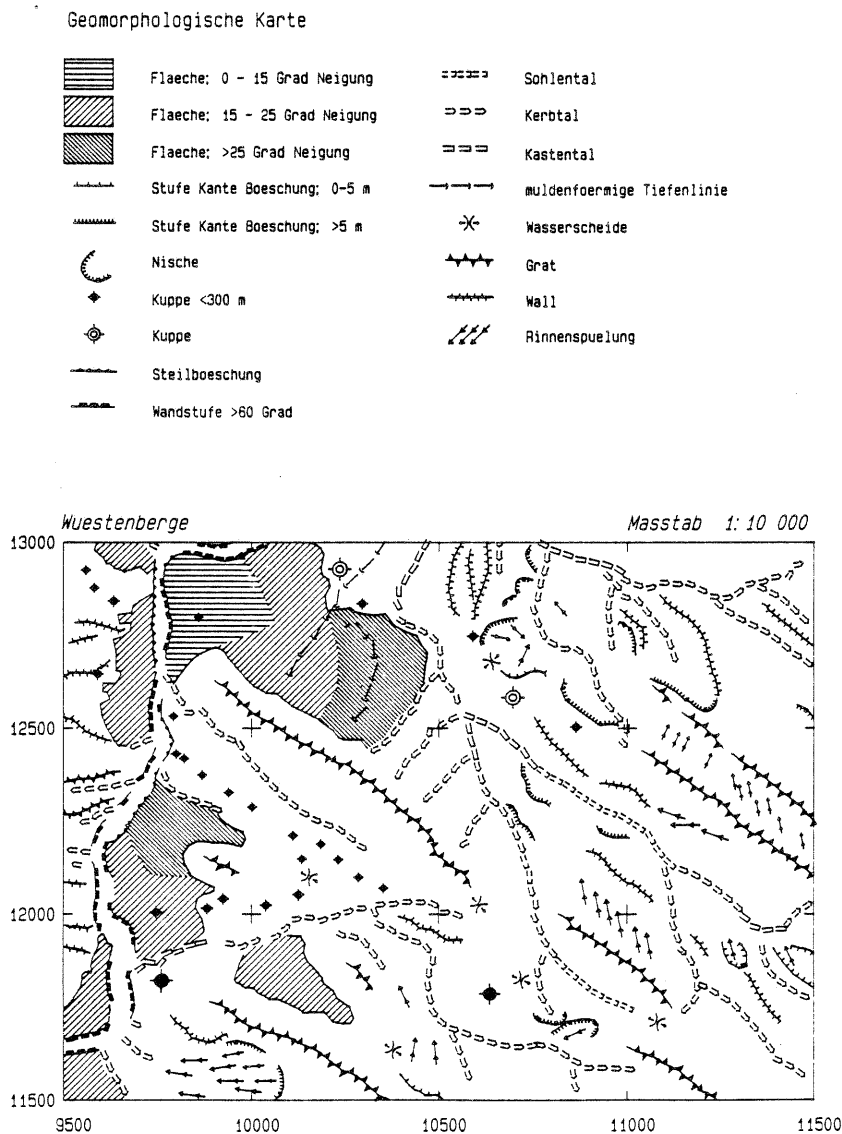


Fig.: 6: Scale 1:10 000 Geomorphological Map

7.1 Thematical Maps

The thematical mapping capabilities are illustrated in Fig. 6 by means of a geomorphological map. Stereoscopic interpretation of air photos is particularly suited to geomorphology, the science of terrain surface configurations. The available programs enable the measurement of differences in elevation, slope angles, surface areas etc. The mapping programs (LINE, AREA) serve to plot steps, edges, slopes, bottom lines or planes with different inclinations. The legend was created with the TEXT program. The elevation profile, which follows a line indicated in the map, rounds off the relief representation (Fig. 7).

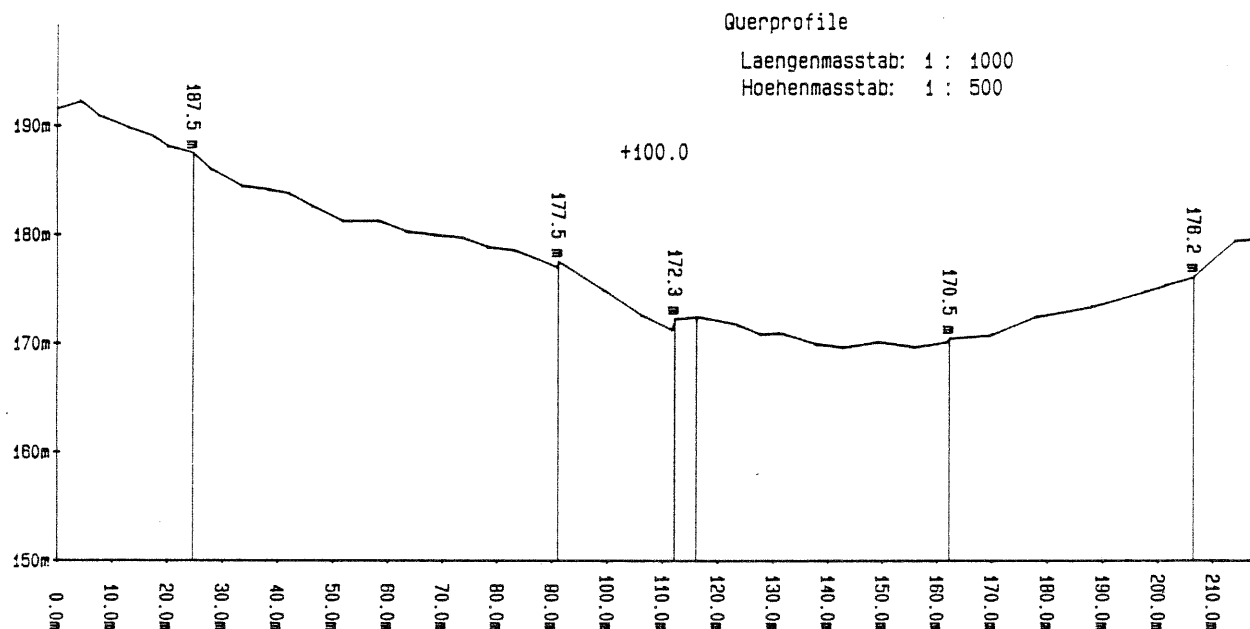


Fig. 7: Elevation Profile

7.2 Photogrammetric Plotting

Examples of graphical and numerical mapping are:

- Production of a scale 1:10.000 land utilization plan (Fig. 8)
- Revision of topographical maps
- Scale 1:100 facade plot from terrestrial stereograms made with the SMK 120

Measurement of digital terrain models using topographically selected points and lines.

Aerotriangulation of model blocks inclusive of point measurement with the Stereocord, transfer of the point data to the HP 1000 minicomputer with the TRANSFER program, and block adjustment with PAT M. The point measurement performance of the G3 Stereocord was determined by means of several test blocks. The Appenweiler block (wide angle, photo scale 1:7500, 10 models, 220 point measurements) yielded the following result:

$$\begin{aligned} \sigma_0 \text{ planimetric: } & \pm 0.2 \text{ m} = \pm 25 \text{ } \mu\text{m} \\ \sigma_0 \text{ elevation: } & \pm 0.2 \text{ m} = \pm 25 \text{ } \mu\text{m} = \pm 0.2 \text{ } \text{‰} \end{aligned}$$

These results are very good (measurement and computations: Fachhochschule für Technik, Stuttgart, and Photogrammetrisches Institut der TU Stuttgart). About 25 minutes per model are required for preparation, orientation and measurement of 6 to 12 points.

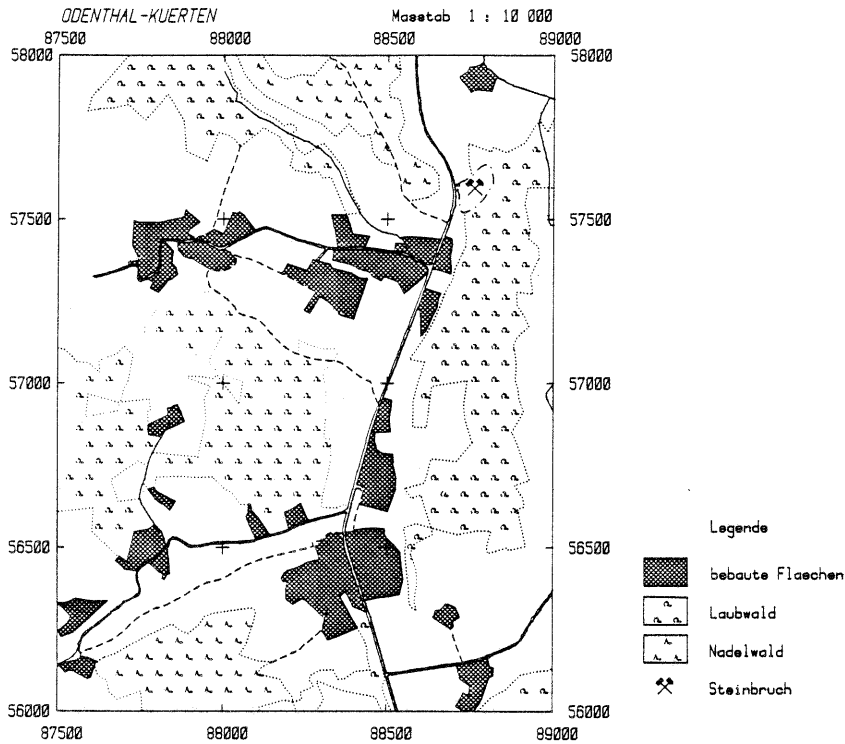


Fig. 8: Scale 1:10 000 Land Utilization Plan

7.3 Terrestrial Plotting

The G3-TERRESTRIAL package allows photographs taken with metric, part-metric and non-metric cameras to be used for topographical applications in the medium and close distance ranges. The attainable precision depends on the instrument precision (see 7.2) and the specific taking conditions.

7.4 Training

The G3 Stereocord is an ideal state-of-the-art instrument for training students in numerical and analytical photogrammetry and in computer-controlled mapping. Major photogrammetric plotting operations such as

- stereoscopic viewing and measurement
- interactive numerical orientation
- computer-supported interactive plotting and
- computer-controlled mapping

have been solved in the G3 Stereocord in a didactically exemplary way. The PILOT program enables the user to develop his own application programs and to integrate them in the G3 software. This is the reason why, in the basic training of photogrammetrists, conventional analog instruments such as the DP1 double projector should be complemented or replaced by modern Stereocord type instruments.

8. Conclusions

The G3 Stereocord is an easy-to-handle universally applicable medium-precision plotting system. It is especially suited for quantitative and graphical photo interpretation. Its modular expansion capability meets economic considerations. Integration in large photogrammetric systems is possible by computer linkage.

Zusammenfassung

Das Stereocord G3 als einfaches analytisches Gerätesystem dient der numerischen und graphischen Auswertung in Photointerpretation und Photogrammetrie. Es besteht aus einem optisch-mechanischen Grundgerät, einem on-line angeschlossenen Tischrechner HP 86 und einem Softwarepaket mit Basissoftware und optionellen Anwendungsprogrammen. Die neue, rechnergestützte Direktkartierung basiert auf einem HP-Plotter und dem G3-GRAPHIC-Softwarepaket mit Kartierung von beliebigen Symbolen, Symbollinien, Flächenfüllung mit Symbolen, Schraffur, Kartenblattvorbereitung und Profilkartierung. Hauptanwendungsbereiche sind: Quantitative Photointerpretation in den Geowissenschaften, Herstellung thematischer Karten, photogrammetrische Punktmessungen mittlerer Genauigkeit, terrestrische Photogrammetrie (Architektur, Archeologie, Unfallwesen, Kriminalistik usw.) und Ausbildung in Photogrammetrie.

Abstract

The G3 Stereocord is a simple analytical instrument system for numerical and graphical plotting in photo interpretation and photogrammetry. It consists of an opto-mechanical viewer, an on-line HP 86 desktop computer and a software package comprising the basic software and optional application programs. Computer-supported direct plotting with an HP plotter and the G3-GRAPHIC software package is new; it allows plotting random symbols, symbol lines, area filling with symbols, hatching, map sheet preparation and profile plotting. Major fields of application are quantitative photo interpretation in the earth sciences, production of thematical maps, medium-precision photogrammetric point measurement, terrestrial photogrammetry (architecture, archeology, accident and criminal investigation etc.) as well as photogrammetric training.

Résumé

Système analytique simple, le Stereocord G3 sert à la restitution numérique et graphique dans les domaines de la photogrammétrie et de la photo-interpretation. Il est composé d'un instrument de base opto-mécanique, d'un calculateur de table HP 86 fonctionnant en régime on-line, ainsi que d'un ensemble de programmes comprenant le logiciel de base et des programmes d'application optionnels. Ce nouveau procédé direct d'établissement de cartes assisté par calculateur fonctionne à l'aide d'un traceur de courbes HP et de l'ensemble de programmes G3-GRAPHIC pour la reproduction graphique de symboles quelconques et de lignes caractéristiques, pour le remplissage de surfaces avec des symboles ou hachures, pour la préparation des feuilles de cartes et pour le traçage de profils. Les applications principales comprennent la photo-interpretation quantitative dans les sciences de la Terre, la rédaction de cartes thématiques, la mesure photogrammétrique de points avec une précision moyenne, la photogrammétrie terrestre (architecture, archéologie, enquête d'accidents, investigations policières, etc.), ainsi que la formation en photogrammétrie.

Literature

- /1/ Mohl, H.: Das Stereocord G3
Bildmessung und Luftbildwesen 50 (1982)
- /2/ - G3 Stereocord (manual)
Zeiss Product Information 51-1120
- /3/ Jordan, E.
Kresse, W.: Die Computer-gestützte quantitative Luftbild-
auswertung mit dem Zeiss Stereocord und seinen
Peripheriegeräten zur Rationalisierung der Feld-
forschungen in den Geowissenschaften.
Erdkunde, vol. 35 (1981)
- /4/ Jordan, E.: Das Ausmaß der rezenten Sandverlagerungen in
bolivianischen Dünengebieten - quantitative
Bildauswertung mit dem rechnergestützten
Interpretationsgerät Stereocord und ihre
wissenschaftliche und praxisrelevante Bedeutung.
Geomorphologie, vol. 43 (1982)
- /5/ Hobbie, D.: Extended Graphical Plotting with the Planicom
39th Photogrammetric Week
September 19 to 24, 1983, Stuttgart
- /6/ idem G3-GRAPHIC (operating instructions)
Zeiss product information 51-1127
- /7/ Faust, H.-W.: The G2 Stereocord. Its Use in Metric Air Photo
Interpretation
35th Photogrammetric Week, 1974, Stuttgart