Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

DIGITAL ELEVATION MODELS: USERS' ASPECTS

K. Kraus[1], E. Aßmus[1], A. Köstli[2], L. Molnar[1], E. Wild[2]

1. Preliminary remarks

A number of institutions are using digital elevation models already; and many institutions are deciding the question these days whether or not to replace conventional methods by digital techniques. It is the purpose of this paper to show what users of digital elevation model techniques can expect of them. The text is based on the Stuttgart Contouring Program (SCOP). Work on this program was started in Stuttgart some 10 years ago, and for the past 8 years it was developped and maintained in collaboration with the Technical University of Vienna |2, 7, 10|.

Requirements of users are not homogeneous and depend much upon the role of the particular user within the institution he is working with. We will use the following classification of users:

a) task-oriented users, in this case photogrammetrists and geodesists, interested in different versions of data acquisition and in the choice of products of the program system,

b) personnel operating the program, concerned with program control capabilities, error handling, and so on,

c) system specialists managing the computer system, interested in operational modes of the program and in interfacing it with I/O devices and other processes.

In this paper, SCOP will be described in terms of the above three user groups, with special emphasis on program operation - as in this respect SCOP has recently been fully revised within the frames of a contract of five road construction authorities of the Federal Republic of Germany, represented by the Federal Institution of Transportation and Road Construction (BAST) in Cologne.

2. Data acquisition options, choice of products

2.1 Profiling a relatively oriented pair of photographs

Originally, the task of deriving contour lines of profiles prompted the development of SCOP. On the one hand, profiling is considerably faster than compiling contour lines, on the other hand, profiles have been waste products of early orthophoto devices. In this case, the computer program performs the absolute orientation of the model, interpolates a regular square (in the XY-plane) grid of heights within the field coordinate system, interpolates within this grid point sequences of contour lines, and creates an output of these lines for some automatic plotter.

Profiling is characterized by a relatively large systematic error of 0.3 to 0.8 °/oo of the flying height above ground. Therefore, a corresponding filtering is necessary to eliminate this systematic scanning error in steep areas and in wooded terrain. In SCOP, linear prediction is used for this purpose.

2.2 Adding formlines and breaklines to the profiles

It was necessary in the first line for increasing the geomorphological quality of the contour lines deduced, to add formlines along hollows and ridges, and especially breaklines to describe sharp changes in the terrain surface. Breaklines are intermeshed with the digital height (elevation) model at its interpolation (figures 1 and 2; |2|). A long series of cases with breaklines and formlines yielded contour lines of excellent quality.

---

[1] Institute of Photogrammetry, Technical University of Vienna

[2] Institute of Photogrammetry, University of Stuttgart

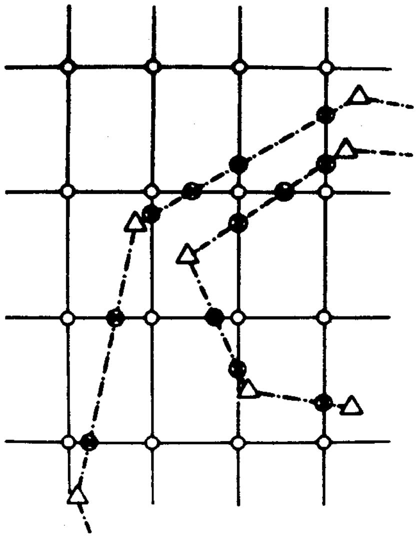


Fig. 1: DHM - rectangular grid with intermeshed breaklines

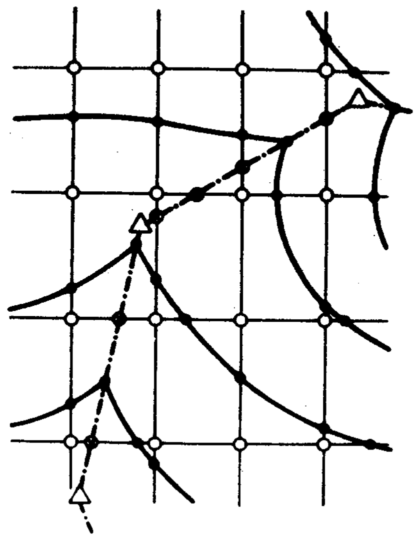


Fig. 2: Contour lines interpolated in a DHM with breaklines

Tests of SCOP products conducted by users (e.g. by the state of Styria) yielded an accuracy characteristic for elevations in flat terrain of 0.15 °/₀₀ of the flying height. The corresponding value for contour lines compiled directly is, as well known, about 0.25 °/₀₀. In areas with characteristic slopes of about 20 %, both methods yield the same accuracy; and in areas with steep slopes, direct compilation of contour lines is superior to their indirect deduction (similar conclusions have been arrived at by Ackermann |1|, on the basis of independent experimental studies). In areas with very complex geomorphology (high mountains), not only the accuracy of the contour lines deduced is unsatisfactory, but the acquisition of formlines and breaklines becomes increasingly expensive. All this yields the following recommendations:

Indirect deduction of contour lines should be used

- in areas with simple terrain forms or terrain forms of average complexity, at all mapping scales;
- in towns and cities, especially for large scale mapping (≥ 1:5,000);
- in wooded areas, especially for small scale mapping (≤ 1:5,000); in larger scales tacheometrical surveying should be used.

Direct compilation of contour lines:

- in areas with very complex geomorphology.

Concerning the growing importance for contemporary technical applications of digital elevation models as compared with the importance of maps with contour lines, there is one more point against the direct compilation of contour lines: contour lines are no adequate basis for the computation of digital height models, except they are complete with breakline information |3|.

2.3 Direct photogrammetric acquisition of point grids and of breaklines

Analytical plotters and analogue photogrammetric devices equipped with digital intelligence are capable of acquiring point grids directly in the field coordinate system. As shown by Rüdenauer |9|, the accuracy of elevations acquired this way increases to 0.1 °/₀₀ of the flying height, if control mechanisms slow down the scanning movement before a recording is due. Such point grids are the first part of the digital terrain model itself, the second part being the breakline points intermeshed with the quadratic grid as indicated in fig. 1.

This method requires the minimum of computation. It is often applied in road construction |6|, where the most important products are profiles and cross-sections, with contour lines playing a subordinate role. Profiles and cross-sections deduced from such DTMs - and naturally from any DTM interpolated in SCOP - contain

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

breaks at crossing breaklines (fig. 3 in |6|). Outline information for profiles and cross-sections is formulated for SCOP in ways used in road construction.

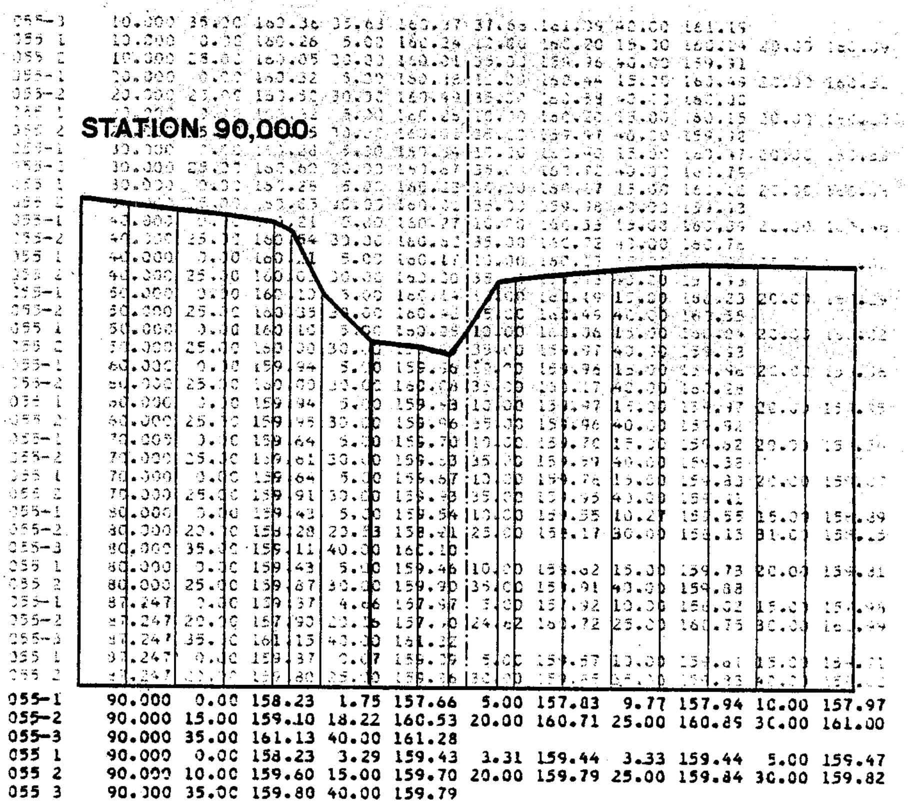


Fig. 3:
Cross section interpolated in a DHM with intermeshed breaklines

2.4 Single points complete with formlines and breaklines

In this case, points are acquired so as to adequately describe the terrain surface by keeping the number of these points at a minimum. Formlines and breaklines gain a special importance in this version of data acquisition. In words of Professor Killian, one is portraying the terrain. This version being characteristic of terrestrial methods, it is sometimes applied in photogrammetric technologies as well.

Adequate processing of such data, with the point density varying widely, is only possible by computer programs capable of locally adapting both the size and the form of computing units to the density and distribution of points in the area to be interpolated. To solve this task, gross computing units of regionally variable size and form are arranged around net computing units of a size constant over the entire DTM. A further important effect of such organization of computing units is an always optimal computing time due to using always an optimal amount of points for interpolating the height of the regular grid.

It can be mentioned in this connection that a disadvantageous characteristic of least square interpolation has been rectified in the latest version of SCOP. In areas without points, or with large intervals between points along breaklines, linear prediction tends to approach the trend surface instead of bridging such gaps in a linear manner. E. Wild succeeded in modifying the prediction method so that this effect is not characteristic of it any more |11|.

Recognizing the invariance of accuracy for different interpolation methods (as long as data remain free of errors)[1], an additional interpolation method -

[1] H. Köhler of Road Construction Authority of Lower Saxony obtained an accuracy of ± 12 cm in flat terrain out of points acquired by tacheometry with a density of about 30 meters - independent of the interpolation method applied.

the "moving tilted plane" - has been built into SCOP, requiring less computational effort as compared with the linear prediction. For the cartographic quality of contour lines deduced from a DTM interpolated by the moving tilted plane is not as high as that gained using the prediction method, this additional fast interpolation is used to create test drawings. However, the method of the moving tilted plane will be applied in final runs in those cases where the main product is the DTM, and where contour lines are considered to be just a representation of it with secondary importance.

The following data describing the computational effort for these two interpolation methods on a SIEMENS 7760 (BS 2000) have been provided by H. Köhler. CPU-times are in both cases low; still, these data justify providing such choice of interpolation methods by SCOP.

Project	Inter-polation	Points single	Points of form-lines	Points of break-lines	grid points	Interp. contour line points	CPU (sec.)
Cochen (A)	pred.	2 274	1 439	204	14 194	11 031	63
"	mov. tilt.	"	"	"	"	"	32
B 51	pred.	1 529	-	-	8 721	19 790	39

2.5 Border lines and elements of the situation

The area of interest can be defined in SCOP by surrounding and by inner polygons. Is such definition missing, SCOP deduces it automatically on the basis of data distribution.

Border lines can be defined along, for instance, streets or supporting walls, to suppress drawing contour lines in these areas (fig. 4).

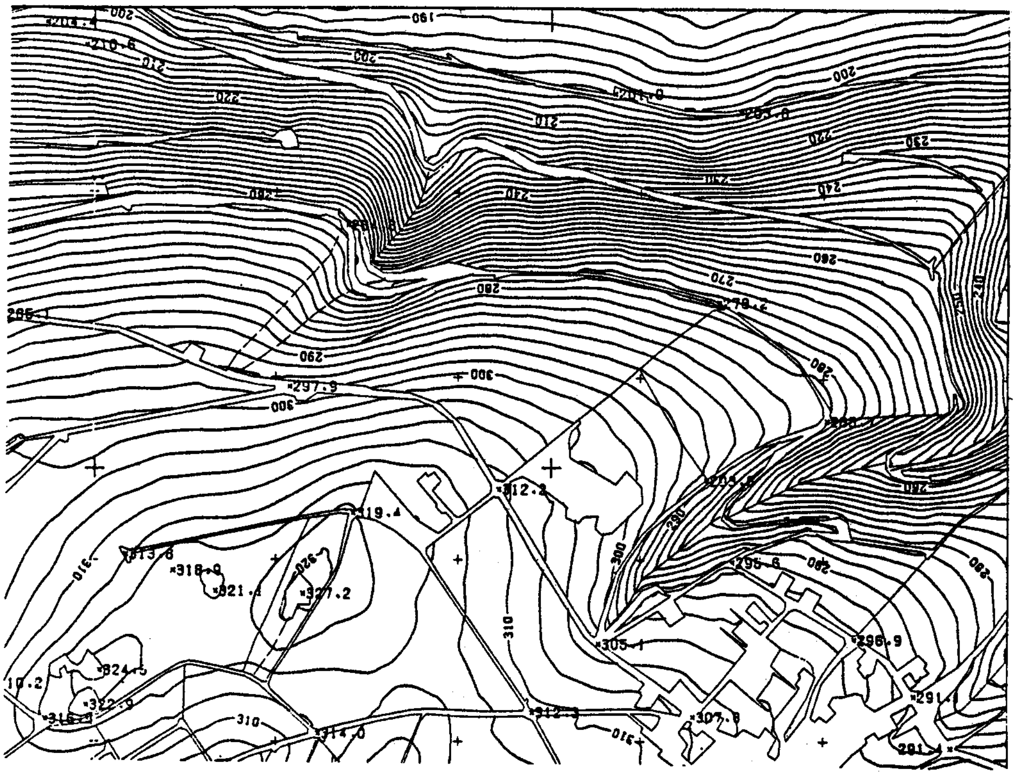


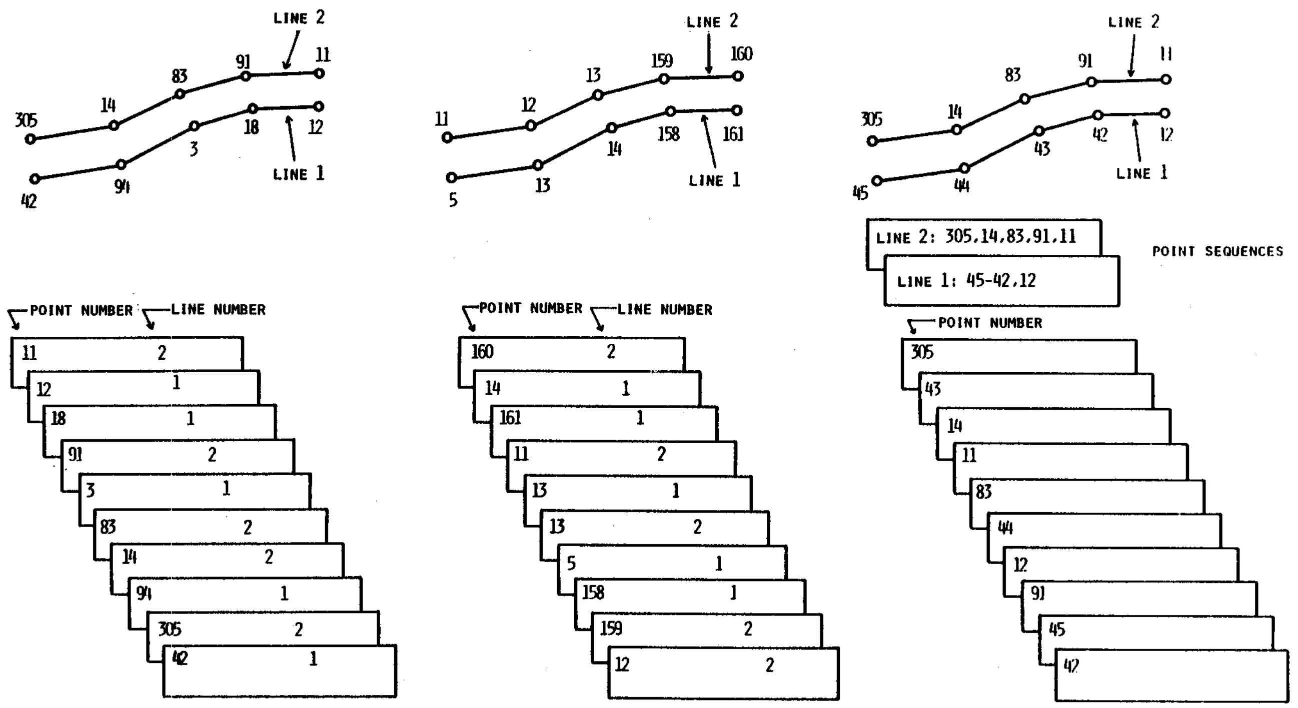
Fig. 4: Contour lines interrupted at internal border lines

Border lines and even breaklines are closely connected with the situation. SCOP does not contain any universal capabilities to represent the situation, still, a simplified map of the situation can be created using SCOP. In addition to points and lines relevant to the DTM, there can be recorded and stored lines important only as elements of the situation.

In this connection, the question of coding input data can be raised. Without going into the details, let us just mention that the left justified two digits of a point number represent the code (breakline, street border, fence, elevation on a bridge, etc.), and the right justified four digits represent a line number or a point number.

For the purpose of terrestrial data acquisition, a special data form has been developped by the Road Construction Authority of the Federal Republic of Germany, containing special codes describing elements of the situation, parallel to the information relevant to the DTM.

In the case of terrestrial data acquisition, grouping together random point sequences into line information represents a special problem. Three different solutions of this task are included in SCOP, as represented in fig. 5.



VERSION 1: SORTING IN SCOP ACCORDING TO LINE NUMBERS (POINT SEQUENCE WITHIN LINES IDENTICAL WITH THEIR ORDER ON INPUT)

VERSION 2: SORTING OF LINE POINTS WITHIN SCOP ACCORDING TO POINT NUMBERS

VERSION 3: POINT SEQUENCES AS DEFINED PAST FIELD WORK

Fig. 5: Versions of collecting line information (terrestrial data acquisition)

3. Processing control and software tools

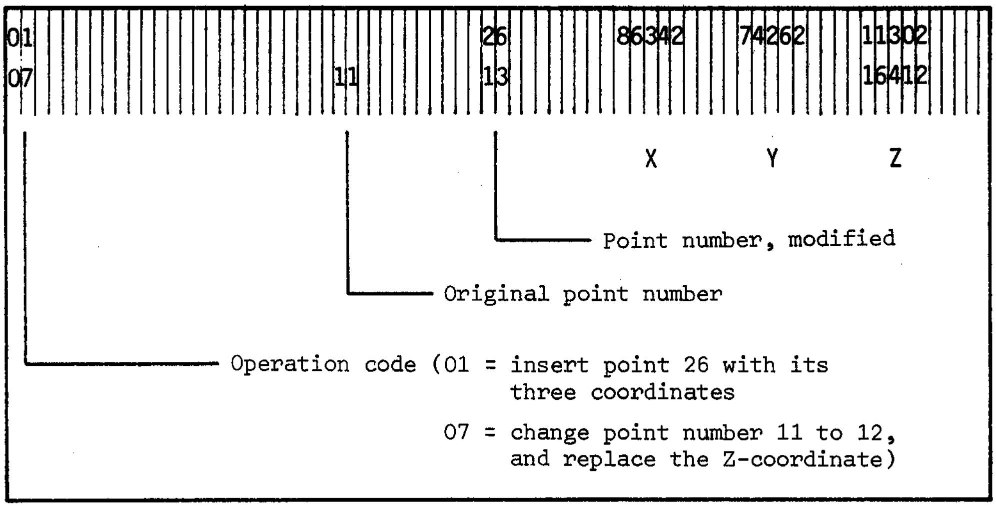
At first, three ways of controlling routes of processing in computer programs will be discussed, yielding the necessary arguments in favour of using in SCOP a command language for this purpose. Special attention is paid to interactive processing.

3.1 Ways of processing control

In the following, three ways of processing control will be represented on two simple examples. In the first example, a point with number 26 is inserted into a list of coordinates (point number, X, Y, Z), and in the second example, the point number 11 should be renamed to number 13, and the corresponding coordinate Z should be modified.

3.1.1 Formatted input

Controlling the process by formatted input, the two lines solving the tasks of the two examples could be:



Tab. 1: Processing control by formatted input

Formatted input is applied mainly in programs running in batch mode of processing. Processing control is solved by processing codes specified on input cards (lines). Data have to be placed in pre-defined columns, where this pre-definition may be overridden by specifying another input format. This way of controlling the route of processing is practicable only in programs with few control codes, and/or large amounts of data.

3.1.2 Menues and masks combined

This technique can only be used from CRT terminals, and therefore it cannot be applied for batch processing. Menues will be written onto the screen (in our case the menue EDIT). Entering a number elicits displaying the menue or mask chosen (in our case a mask). Having filled in the mask (= form), the menue appears again. Typing RETURN evokes a menue one step higher in the hierarchy.

This technique provides the user with a detailed guidance along the capabilities of a program. Such guidance is very much appreciated by the beginning, unexperienced user. In a routine production, however, such detailed guidance becomes boring, or even annoying, especially in cases with the decision tree becoming more complex. Furthermore, menues may become more complicated with the number of branches to be chosen of growing. In filling in masks, many superfluous CONTINUEs may become necessary, because quite often just one or a few elements of the active mask are needed. Furthermore the technique of menues and masks requires expensive hardware: filling in masks needs a cursor controlled by the program; a fast communication between terminal and computer is important as well.

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

MENUE E D I T
1 I N S E R T
2 D E L E T E
3 A L T E R
LINE NO. OR RETURN 1

P U N K T N U M M E R 26
X 86342
Y 74262
Z 11302

MENUE E D I T
1 I N S E R T
2 D E L E T E
3 A L T E R
LINE NO. OR RETURN 3

O L D N U M B E R 11
N E W N U M B E R 13
X CONTINUE
Y CONTINUE
Z 16412

Tab. 2:
Example of the combined technique of menues and masks
(Italics appear on the screen; standard letters are typed in by the user)

3.1.3 Command language

Development of an adequate command language was started by H. Kager |5|, and set forth by A. Köstli and L. Molnar. The two examples can be expressed in terms of a command language (without considering any details of the syntax |5|), as follows:

INSERT, NUMBER = 26, X = 86342, Y = 74262, Z = 11302;

ALTER, OLDN = 11, NEWN = 13, Z = 16412;

Tab. 3: Example of the communication with a command language

Contrary to the menue technique, the analysis of the mnemonic elements of the language has to be performed by the program. This has been solved nearly exclusively by using standard FORTRAN IV; only two small functions (pack/unpack) are machine dependent (even these are standard in FORTRAN 77).

A command language can be advantageously applied both in interactive and in batch modes of operation. Mainly for this reason, it has been chosen to solve processing control in SCOP. Depending upon the configuration, software, and organization of different computer centers, and upon the working habits of the user, both modes of operation are applied, and supported by SCOP. Furthermore, switching from one mode of operation to the other is extremely useful as well: program sections requiring extensive processing control (such as data editing, error searching), can be performed in an interactive session, and others, characterized by extensive computations or I/O processes (data input; interpolation; plotting) are generally (but not necessarily) run in batch mode.

To a beginner, working with a command language may appear to be more difficult than working with the combined menue and mask techniques: a steady guidance is missing in the first case. To ease this problem, the user is allowed to type a question sign at any stage of the control input; this causes the command language to display the set of mnemonic elements, data types, etc.,available at that instant. So, typing

INSERT, ?

will be followed by displaying the corresponding parameters of the directive

INSERT; NUMBER, X, Y, Z.

Another counter argument against using mnemonics (e.g. English words) is the problem of typing errors. The text interpreter in our command language is able to interpret abbreviated forms, as long as they remain unique among the active set of elements. Instead of typing INSERT, for example, one could type INSRT, IS, INS - or even INSERTPOINT (but not: INSPOINT).

One of the main advantages of using a command language is the reduction of control input to a necessary minimum (e.g. no CONTINUE actions are necessary, so characteristic of filling in masks). To still further minimize typing work, the capability of using a command file is provided. A command file contains some command procedures, different series of commands, or groups of data. These can be activated as control input by typing a single directive - evoking in this way the execution of some typical series of commands or the input of, for instance, field coordinates of control points, etc. Using command procedures stored on the command file, the user can create for himself a personal guidance in the form of comments on the command file displayed on the screen by the command language. Commands input from the command file can be modified interactively by the user before their execution.

3.2 Software tools in SCOP

A program system to process terrain height information should be able to work with just a few control parameters in a standard case. To achieve this, different control parameters are provided with corresponding defaults; and the program corrects some errors automatically. Furthermore, the personnel operating the program has to be given tools enabling error detection in the data, data correction, and defining program output to correspond to different requirements.

For two examples, the minimum on control input that is necessary:

a) Calculation of the DHM out of the photogrammetic data

PROJECT, DATAFILE=NEW, CODE=*(Projektname);*

MODEL;[1]

GROUND, REFSYS=FILE;[2]

MODDAT;[3]

ABSOR, XY=.2, Z=.3;[4]

RETURN;[1]

STOP;

DHM;[5]

PRED, SCAN, TREND=TILT,FUNCTION=CURLIN;[6]

[1] Model opens the segment of directives serving the purpose of photogrammetric data input; this segment is closed by the directive RETURN. This entire segment could be replaced by the single directive managing input of terrestrial data.

[2] Input of control point coordinates (possibly the result of an aerial triangulation) from a file.

[3] Input of one photogrammetric model (data format corresponds in every respect to the defaults).

[4] Automatic error detection and elimination in the process of absolute orientation using these tolerances.

[5] Automatic deduction of the surrounding border line, of the mutually overlapping computing units, and automatic definition of the grid of the DHM.

[6] Prediction of the DHM (SCAN: elimination of systematic scanning errors, TREND=TILT: tilted plane as trend surface for the prediction, FUNCTION=CURLIN: bell curve as covariance function in computing units without breaklines, and straight line as covariance function in computing units with breaklines).

b) Deriving contour lines from the DHM

```
CONTOURS, LEVELS=INTERVAL=5;¹
PINIT, SCALE=5000;²
ISOPLOT;³
SYMBOL, CONTROL, SPOT, SINGULAR;⁴
STOP;
```

[1] Interpolation of 5m-contours.

[2] Initializing map sheet (legend, frame, coordinate grid, etc.)

[3] Output of the contours in ways as defined by defaults.

[4] Output of control points, of spot heights and of elevations off the terrain surface (=SINGULAR).

In many cases such a small amount of control input will yield adequate results, to a certain part as SCOP eliminates a series of data errors automatically. For instance, ABSOR detects and eliminates blunders using data snooping techniques, extended to checking correlations of residuals |8|. Another example of automatic handling of erroneous data is the way of data deletion on the basis of CANCEL-codes set at data acquisition time.

In those cases, however, where the program cannot handle the errors automatically, initiative is put into the hands of the user to analyse and to correct data, applying software tools provided in SCOP. A corresponding interactive session is typically started in the following way:

```
OPMODE, INTERACTIVE;
OUTPUT, LIST=FULL, DISP;¹
PROJECT, DATAFILE=OLD, CODE=(Projektname);²
```

[1] Detailed output onto the listfile (LIST=FULL) and onto the screen (=DISP).

[2] This way, the DATAFILE is re-opened, with the points transformed into the field coordinate system on it. The DATAFILE is an important transient product, it is used by different program segments, and its compressed sequential form is often stored for later use on magnetic tape (s. chapter 4).

3.2.1 Directive LIST

With (for instance)

```
        ⎧ DATAFILE  ⎫
        ⎪ MODEL = i ⎪
LIST,  ⎨ PROFILES  ⎬  ;
        ⎪ BREAKL    ⎪
        ⎩ BOARDER   ⎭
```

it can be decided whether the entire DATAFILE,or just the data of model i, or all profile points, and/or breakline points, and/or all border line points,etc., are to be listed. WINDOWs can be defined by entering corresponding XYZ, or XY, or just Z-values. The art of listing can be specified by several different parameters. Listings are paged for the screen, and in interactive mode of operation, past each page user decisions are repeatedly possible.

3.2.2 Directive CHECK

This directive enables checking - especially for line information - the distance in XY and/or in Z between points that should be close to each other corresponding to their sequence within lines. Such checking is especially important for data gained by terrestrial data acquisition methods, but it may detect dangerous errors in photogrammetric data as well, for instance when two lines have been recorded immediately one after another, without the line number changed. Furthermore, improper crossings within lines can be detected with this directive CHECK.

3.2.3 Directive MATRIX

With MATRIX a scheme of point distribution can be created on line printer or on any alphanumeric screen. Choosing contents to be represented is similar to that in directive LIST (or in CHECK, and in a series of other directives).

The left side of fig. 6 corresponds to

MATRIX, DATAFILE;

and the right side of the same figure to

MATRIX, DATAFILE, Z;

The first case represents a short coded form of data types (+ single points, * breaklines, etc.). The second case (with parameter Z) creates a scheme with the codes on it corresponding to one of the 14 layers, elevations being distributed to (1,2, ... 9, A, ... E); improbably large elevation differences within one facet of the matrix are represented in this second case by printing an * instead of the elevation code.

```
-------------------------------
I      +++ ++++*++**          I
I        ++++ **+**           I
I      +++++ ++*+*            I
I     + ++ ++++*+*            I
I     + ++++ ******           I
I     ++ ++++**+*+***     **+ I
I  * ++++ +**++* +++*+ **++++ I
I    +++ ++****** ++++**+++ +++I
I ***+ ++++****+++ ++**+++++++++++I
I *+++ +++**+++++**++*+++++++ I
I *+++ +++** +++*******+++++  I
I * ++++++**+++ +**+++**+ +   I
I * ++*****+++ +*+++          I
I ***********+ +++*+          I
I *+    +******+++*+          I
I**++++    +*******++         I
I*+++++++ *++******           I
I*+++++++ *+ ++++****+        I
I*++++++++*++++ ++**          I
I ++++++++*+ ++ + **+         I
I*++ +++++*+ ++   +           I
I*++++ ++*                    I
-------------------------------
```

```
-------------------------------
I      332 21111112           I
I        3221 11113           I
I      33322 21121            I
I     3 32 2221122            I
I     3 2222 111223           I
I     32 22211212222     334  I
I  4 3222 211222 22222 333456 I
I    332 2212221 222223336 779I
I 543 3322212222 22233359999ABI
I 4443 323113333333336AAAC9B  I
I 4443 33321 33333345AACED    I
I 4 4333332233 33338AAC E     I
I 4 4434322333 333*A          I
I 34333333233 3333            I
I 44    33322333334           I
I644443    322222347          I
I4444333 333322223            I
I4433333 33 33333349          I
I443333332333 3333            I
I 444444334 43 3 337          I
I444 444434 44  4             I
I54444 443                    I
-------------------------------
```

Fig. 6: Output of the DATAFILE by directive MATRIX
(to the left: point codes, to the right: Z-codes)

3.2.4 Directive QUICK

QUICK creates on line printer or on alphanumeric screen a scheme containing individual points with those of their characteristics requested by parameter input. The points to be represented are chosen in the same way as in LIST or MATRIX. Fig. 7 has been created by entering

QUICK, BREAK, Z, WINDOW=(corner point coordinates);

Instead of defining Z, one can request the point numbers, or, for instance, the UPDATE addresses (3.2.6).

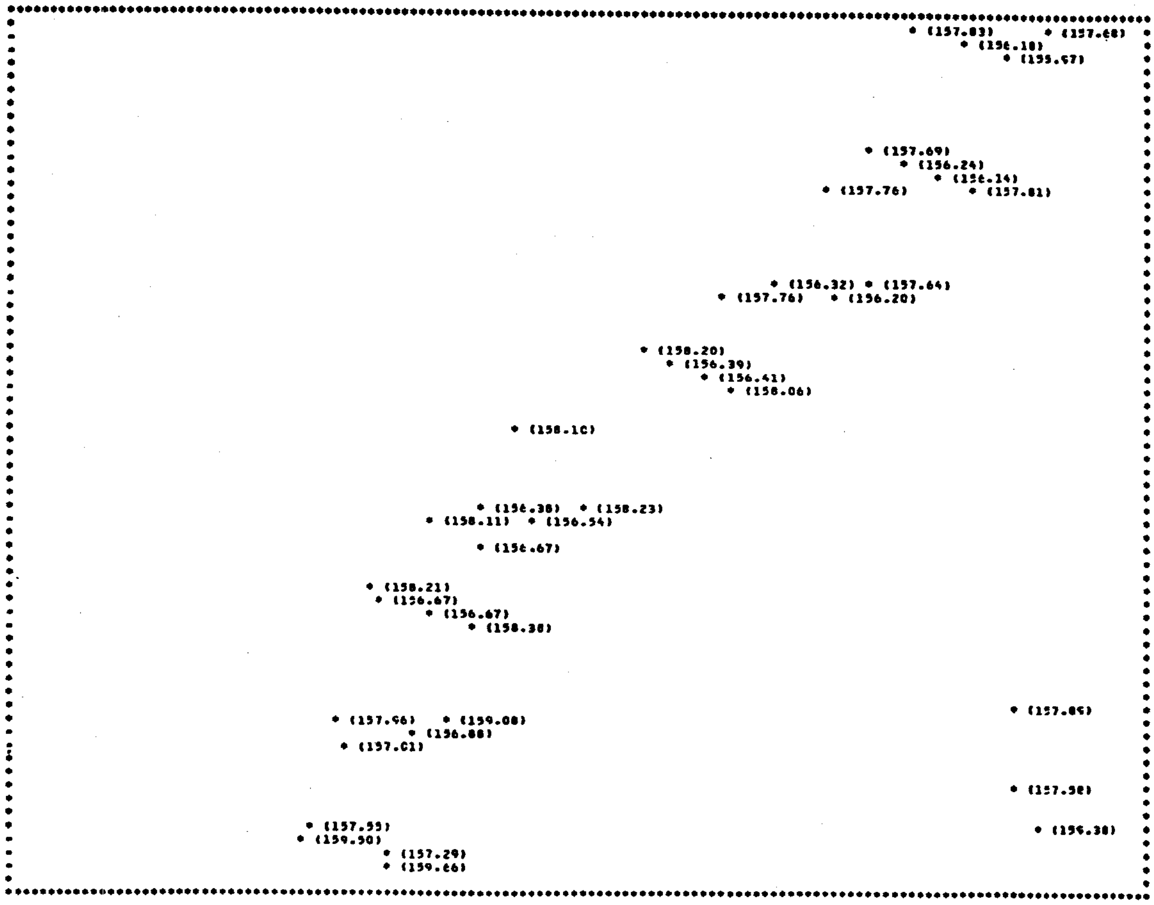


Fig. 7: Z-coordinates of breaklines output via directive QUICK

3.2.5 Directive DRAW

This directive serves to create exact drawings (plots) of the specified contents of the DATAFILE. Fig. 8 was produced by entering

PINIT, SCALE=500, CROSSES=25, FRAME=(FREIBERG);[1]

DRAW, RANDOM, PSYMBOL=3, ADDRESS;

DRAW, BREAKLIN, Z, LSYMBOL=2, PSYMBOL=7;

[1] PINIT has to precede a series of DRAW directives; it initializes the plot, and outputs the frame, legend, etc.

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

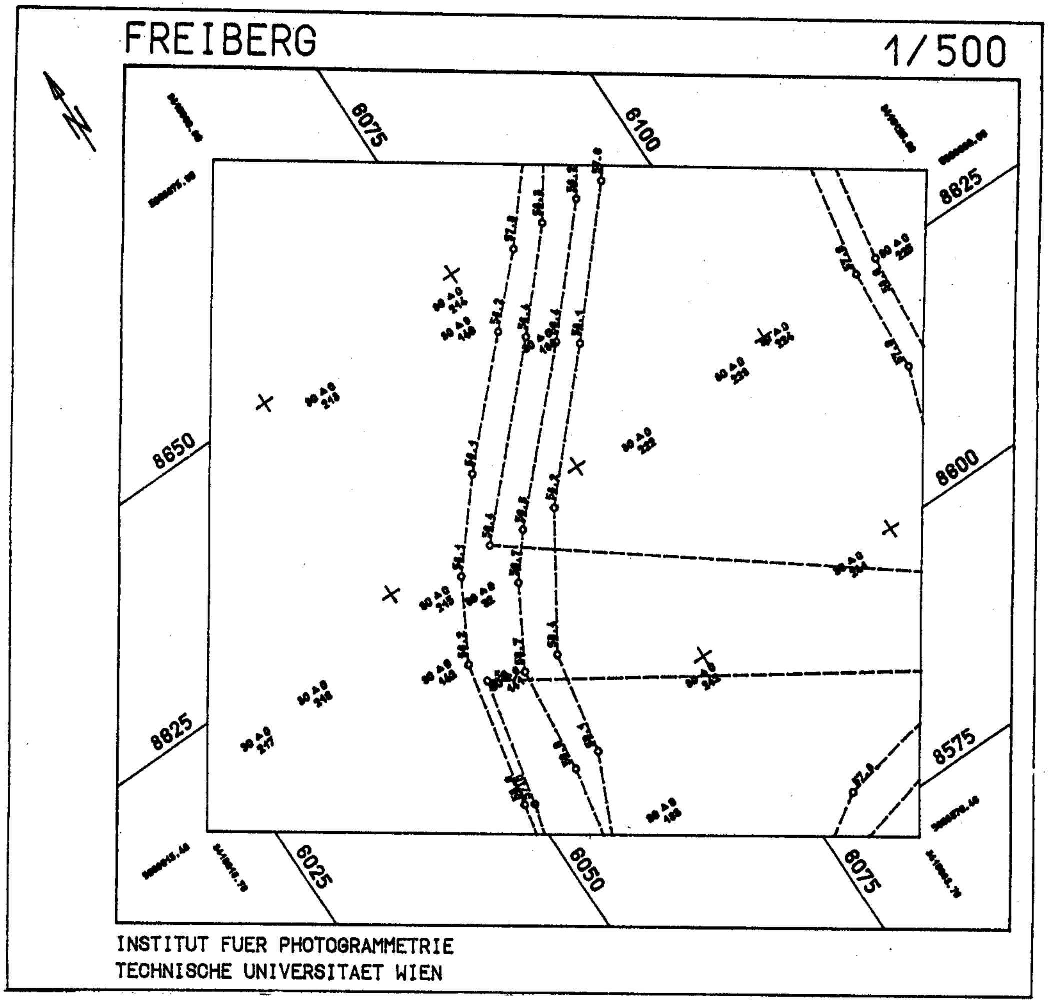


Fig. 8: Data plot of single points (=RANDOM) and of breakline points (=BREAKLINES); other parameters to the directive DRAW: PSYMB=3: triangle, PSYMB=7: circle, LSYMB=2: broken line, Z: with Z-coordinates, ADDR: with UPDATE-addresses.

3.2.6 Directives UPDATE and CHANGE

With these two directives, data editing is possible (DELETE, INSERT, REPLACE, MOVE, COPY, etc.). The addresses necessary can be defined using, for instance, directives LIST, QUICK, DRAW, etc., or these addresses can be taken directly from the messages indicating the errors to be corrected.

3.2.7 Directives FAST and GRIDIN

Both of these directives activate very fast interpolation algorithms, mostly to create test drawings. Entering FAST, MEAN; starts the interpolation by the "moving average", and FAST, TILT; by the "moving tilted plane".
GRIDIN creates the DHM on the basis of input data distributed in a regular grid pattern, with breaklines annexed; the process involves some simple interpolation (mainly for checking purposes, and possibly to handle systematic scanning errors).

3.2.8 Some parameters to directives CONTOURS and ISOPLOT

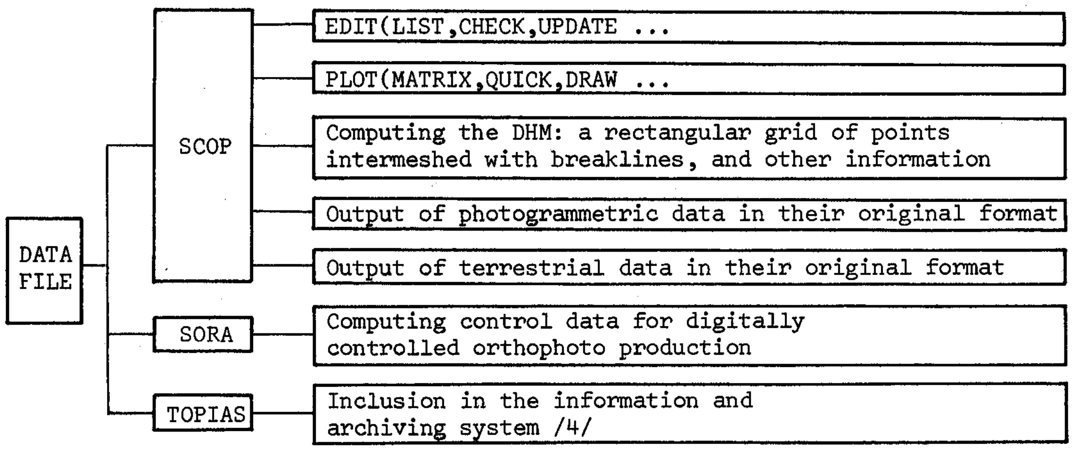
Capabilities of these two directives enable the plotting of contour lines at regular intervals, or at specific levels as defined by parameter input. Parameters of ISOPLOT define which lines are to be plotted and the art of their plotting (periodical switching from pen to pen, contour line elevations to be plotted, continuous and broken line patterns, etc.).

4. Program interfaces to the hardware and software environment

System specialists managing computer systems are especially interested in interfaces. A program system with numerous interfaces increases the programming effort in creating the system, while at the same time these interfaces enable better integration of the program within an environment of software and of hardware. In the following, the three most important interfaces of SCOP will be described.

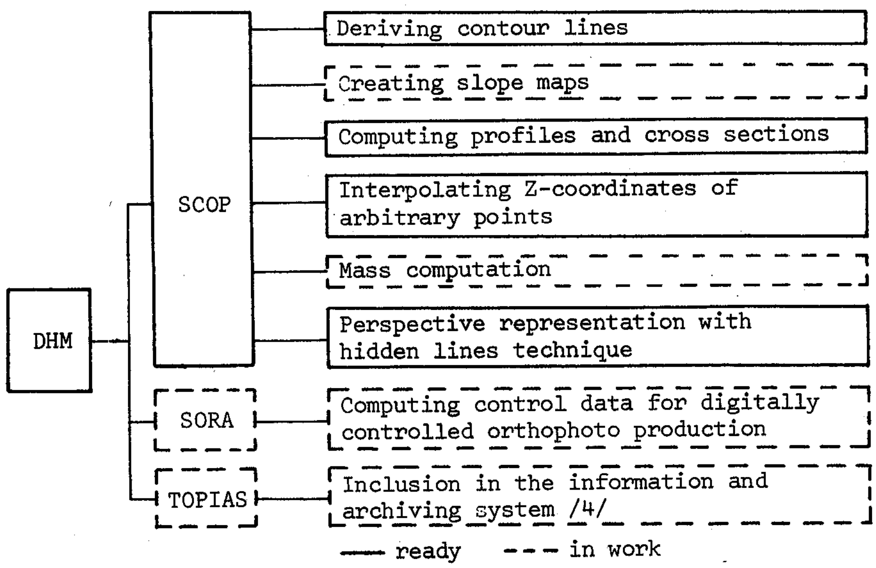
4.1 DATAFILE

After processing CANCEL codes on input and after transforming the data into the field coordinate system, a direct access DATAFILE is created with a structure similar to that of databank. This structure enables a very fast access to the individual data, even on very large DATAFILES. The DATAFILE is used then by different segments of SCOP, and by other programs as well.



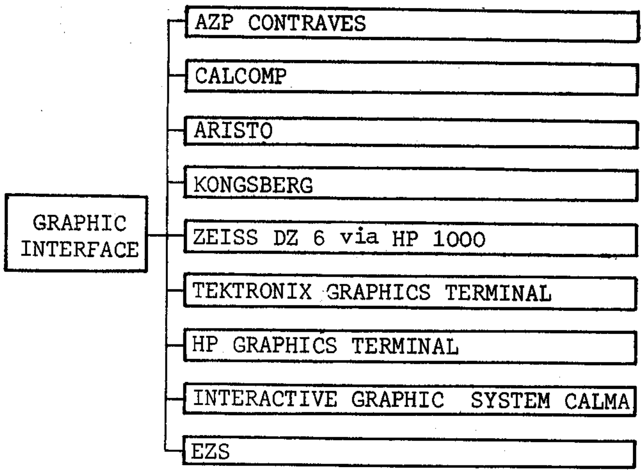
4.2 The DHM: a rectangular grid of points intermeshed with breaklines

A series of programs use this interface, other programs to use it are in work.



4.3 Graphic interface (PLOX)

This interface makes SCOP fully independent of graphic output devices. The AKIMA interpolation is used to output additional points along curves necessary for plotters without interpolating intelligence. Via the graphic interface a connection to an interactive graphic system has been realized, enabling graphic editing of the output. At this point, the following graphic output devices are integrated into PLOX:



EZS is the universal graphic interface of the Road Construction Authorities of the Federal Republic of Germany, applied by numerous private and governmental institutions.

4.4 Hardware requirements

The capability of SCOP to operate in both interactive and in batch mode makes it possible to run it, on the one hand, on hardware configurations with a minimum of peripherals, and, on the other hand, to make full use of modern peripherals, such as alphanumeric and/or passive graphic CRT terminals.

This free choice among the two basic modes of operation along with numerous other qualities of SCOP make it capable of accommodating to a changing environment, or to the changing working habits of its operator. The three most important interfaces provide for integrating SCOP in many-sided software and hardware environments, including different successor programs as developped by users. The graphic interface makes the user independent of graphic output devices, and it has even the potential to interface SCOP (in a future time) to any interactive graphic system. SCOP can be run on powerful minicomputers as well as on large computer systems.

5. Closing remarks

What was started 10 years ago used to be a "contouring program", but in these years it developped into a powerful and many-sided program system to process terrain information (complete with thematic information). Although contour lines are still a fine and much needed product, they become to be secondary in their importance as compared with a qualified DHM.

The most important interface - that between the program and its user - has been developped to accommodate to the working habits of the user, and to make use of his human capacities. Not the computer,but the user controls the process. The user is given many-sided and refined tools to realize his ideas.

References

|1| Ackermann, F.: The accuracy of digital height models. Schriftenreihe des Instituts für Photogrammetrie der Universität Stuttgart, Heft 6, 133-144, 1979.

|2| Assmus, E.: Die Behandlung geomorphologischer Strukturen im Stuttgarter Höhenlinienprogramm. Schriftenreihe des Instituts für Photogrammetrie der Universität Stuttgart, Heft 1, 131-146, 1975.

|3| Brandstätter, L.: Exakte Schichtlinien und topographische Geländedarstellung. Sonderheft 18 der Öst.Z.f.V., Wien 1957.

|4| Haitzmann, H., Kraus, K., Loitsch, J.: Eine Geländehöhendatenbank für die digital gesteuerte Orthophotoproduktion. Österr. Zeitschr. f. Verm. u. Photogr. 68, 157-169, 1980. Englisch: Presented paper, Commission IV, 14. ISP-Congress, Hamburg 1980.

|5| Kager, H.: Das interaktive Programmsystem ORIENT im Einsatz. Presented paper, Commission V, 14. ISP-Congress, Hamburg 1980.

|6| Köhler, J., Kraus, K., Schulze, K.: Anwendungen eines digitalen Geländemodelles bei der Planung und dem Bau von Straßen. Invited paper, Kommission 6, 16. FIG-Kongreß, Montreux 1981.

|7| Kraus, K.: Weitere Entwicklungen und Anwendungen der digitalen Höhenlinienkartierung und des digitalen Geländemodelles. Schriftenreihe des Instituts für Photogrammetrie der Universität Stuttgart, Heft 1, 147-157, 1975.

|8| Molnar, L.: An extended blunder elimination procedure. Presented paper, Commission III, 14. ISP-Congress, Hamburg 1980.

|9| Rüdenauer, H.: Experimentelle Genauigkeitsanalyse digitaler Höhenmodelle. Presented paper, Kommission IV, 14. ISP-Kongress, Hamburg 1980.

|10| Stanger, W.: Erfahrungen mit dem Stuttgarter Höhenlinienprogramm. Schriftenreihe des Instituts für Photogrammetrie der Universität Stuttgart, Heft 1, 113-130, 1975.

|11| Wild, E.: Interpolation with weight-functions - a general interpolation method. Presented paper, Commission III, 14. ISP-Congress, Hamburg 1980.

Abstract

The requirements made of digital height models from the point of view of the user are shown against the background of 10 years of development and varied practical application of the Stuttgart contour line program SCOP. When the development was started, the sole purpose was to derive the contour lines from profile data of the relatively oriented model by computer. Working out the first examples showed that satisfactory results could not be obtained from profile data alone; the break lines have to be included in the data acquisition and processing.

Although the representation of the contour lines remains in practice an important result even today, the gridded DHM supplemented with the break lines is becoming more and more the centre of interest. This DHM is the starting-point for a number of follow-up programs. Particular emphasis will be placed in the lecture on the follow-up programs for road construction, since SCOP, among other things, was acquired by five road construction authorities in the Federal Republic of Germany. As a consequence of this application in road engineering, photogrammetric data acquisition (with large numbers of points) and terrestrial data acquisition (extreme variations in density of points) have now come to be of equal importance in SCOP.

Besides the demands made by the practical user (photogrammetrists, surveyors, etc.) on a program system, the requirements of the user in the data processing field cannot be ignored. The latter is chiefly interested in communication with the program system. In SCOP the operator communicates by means of a command language, which on the one hand permits batch as well as interactive operations, and on the other hand permits guiding, as in the menu method. For data processing, and in particular for rapid detection of critical data constellations, the operator is provided with so-called "tools". For example, the point and line output of the data sets, both on graphical displays and tracing instruments and on alphanumerical displays and line printers are such tools. This output is again the basis of the various updating possibilities for data correction, etc.

Finally, the versatility of the program system is discussed, in order to demonstrate on the one hand its flexibility, and adaptability to various computer configurations and tracing instruments, and on the other hand the possibilities of connection to other program systems. Particular reference is made to the transfer of the edited basic data and the gridded DHM extended by the break lines to a terrain height data bank.

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

Anforderungen an das digitale Höhenmodell aus der Sicht des Anwenders

Zusammenfassung

Vor dem Hintergrund der 10-jährigen Entwicklung und eines vielseitigen praktischen Einsatzes des Stuttgarter Höhenlinienprogrammes SCOP werden die Anforderungen an das Digitale Höhenmodell (DHM) aus der Sicht des Anwenders aufgezeigt. Am Beginn der Entwicklung ging es nur um die Aufgabe, aus Profildaten des relativ orientierten Modelles die Höhenlinien rechnerisch abzuleiten. Die Bearbeitung der ersten Beispiele führte zu der Erkenntnis, daß befriedigende Ergebnisse aus Profildaten allein nicht gewonnen werden können. In die Datenerfassung und -verarbeitung müssen die Geländekanten einbezogen werden.

Obwohl das Höhenlinienbild in der Praxis auch heute noch ein wichtiges Ergebnis darstellt, rückt das rasterförmige, um die Geländekanten ergänzte DHM immer mehr in den Mittelpunkt des Interesses. Dieses DHM ist nämlich der Ausgangspunkt vieler Folgeprogramme. In dem Vortrag werden besonders die Folgeprogramme für den Straßenbau herausgestellt, da SCOP u.a. von fünf Straßenbauverwaltungen der Bundesrepublik Deutschland übernommen wurde. Der Einsatz im Straßenbau hat dazu geführt, daß in SCOP die photogrammetrische Datenerfassung (sehr große Punktmengen) und die terrestrische Datenerfassung (sehr unterschiedliche Punktdichte) nun gleichrangig nebeneinander stehen.

Neben den Anforderungen des sachbezogenen Benutzers (Photogrammeter, Geodät, etc.) an ein Programmsystem dürfen diejenigen des datenverarbeitungstechnischen Benutzers nicht übersehen werden. Letzterer interessiert sich vor allem für die Kommunikation mit dem Programmsystem. Mit SCOP kommuniziert der Bearbeiter mittels einer Kommandosprache, die einerseits den Stapel- als auch den interaktiven Betrieb und andererseits eine Führung, wie sie von der Menue-Technik her bekannt ist, erlaubt. Zur Verarbeitung der Daten und insbesondere zum raschen Aufdecken kritischer Datenkonstellationen werden dem Bearbeiter sogenannte Werkzeuge an die Hand gegeben. Solche Werkzeuge sind z.B. die punkt- und linienweise Ausgabe der Datenbestände sowohl auf graphischen Bildschirmen und Zeichengeräten als auch auf alphanumerischen Bildschirmen und Zeilendrucken. Diese Ausgabe ist wiederum Grundlage für die verschiedenen UPDATE-Möglichkeiten zur Datenkorrektur, usw.

Zum Schluß wird auf die wichtigsten Schnittstellen des Programmsystemes eingegangen, um einerseits die flexible Anpassung an verschiedene Computerkonfigurationen und Zeichengeräte und andererseits die Verbindungsmöglichkeiten mit anderen Programmsystemen aufzuzeigen. Auf die Überführung der bereinigten Rohdaten und des rasterförmigen, um die Geländekanten erweiterten DHM in eine Geländehöhendatenbank wird besonders hingewiesen.

Exigences pratiques posées par les modèles de terrain numériques

Résumé

A l'égard du développement d'une dizaine d'années et aux multiples utilisations pratiques du programme des courbes de niveau SCOP de Stuttgart, le conférencier indique les exigences pratiques posées aux modèles de terrain numériques (DHM). Au début du développement il s'agissait seulement de dériver numériquement les courbes de niveau des données de profil du modèle orienté relativement. Cependant, le traitement des premiers exemples a révélé qu'il n'était pas possible d'obtenir des résultats satisfaisants seulement à partir des données de profil. Il faut intégrer également l'accident de terrain dans la saisie et le traitement des données.

Bien que dans la pratique la représentation du terrain au moyen des courbes de niveau revête toujours une grande importance, le DHM en forme de trame, qui est complété par l'accident de terrain, suscite un intérêt de plus en plus grand. Ce modèle de terrain numérique est à la base de nombreux programmes de traitement ultérieur des données. L'exposé traite particulièrement ces programmes en matière de la construction de routes étant donné que le SCOP a été adapté entre autres par cinq administrations des Ponts et Chaussées de la République Fédérale d'Allemagne. Cette utilisation dans la construction de routes a eu pour conséquence que dans le SCOP la saisie photogrammétrique des données (grande quantité de points) et la saisie terrestre des données (grande diversité de la densité des points) se situent maintenant au même niveau.

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

Outre les exigences de l'utilisateur (photogrammètre, géomètre) posées à un système de programmes, il ne faut pas négliger les exigences de l'utilisateur responsable du traitement des données. Ce dernier s'intéresse avant tout à la communication avec le système de programme. Avec le SCOP l'utilisateur se sert d'un langage d'instructions qui permet non seulement le traitement différé et le traitement interactif mais encore une conduite telle qu'elle est connue de la technique par menu. Pour traiter les données et plus particulièrement pour découvrir rapidement les constellations critiques des données, l'utilisateur peut se servir des moyens suivants: sortie point par point et sortie linéaire des données sur écrans graphiques et tables traçantes de même que sur écrans alpha-numériques et imprimantes de lignes. Cette sortie est à la base des différentes possibilités UPDATE pour la correction des données, etc.

En conclusion l'auteur traite la structure de l'ensemble du système de programmes pour démontrer d'une part l'adaption flexible à divers systèmes d'ordinateurs et tables traçantes et d'autre part les possibilités de liaison avec d'autres systèmes de programmes. Il mentionne particulièrement la transmission des données de sortie corrigées et du DHM en forme de trame élargi par l'accident de terrain à une banque de données de modèles de terrain.

Exigencias respecto a los modelos digitales del terreno, consideradas desde el punto de vista del usuario

Resumen

Considerando los diez años dedicados al desarrollo del programa de curvas de nivel de Stuttgart SCOP y su amplia utilización práctica, se exponen las exigencias respecto a los modelos digitales del terreno (MDT), formulados por el usuario. Al inicio del desarrollo, se trataba únicamente de derivar las curvas de nivel a partir de los datos de perfiles del modelo orientado relativamente y ello por vía de cálculo. Los primeros ejemplos, sin embargo, demostraron que los datos de perfiles por sí solos no permitieron obtener resultados satisfactorios; en la recopilación y en el proceso de los datos era necesario incluir los cantos del terreno.

Si bien la representación de las curvas de nivel sigue correspondiendo en la práctica a un resultado muy útil, el MDT en forma de cuadrícula completado por los cantos del terreno resulta siempre más interesante, por constituir la base de muchos programas sucesivos. En la presente conferencia se insiste sobre todo en los programas sucesivos para la construcción de carreteras, puesto que cinco Departamentos de Obras Públicas de la República Federal de Alemania trabajan con SCOP. El empleo en la construcción de carreteras ha tenido por resultado que en SCOP se consideren equivalentes la recopilación de datos fotogramétrica (cantidades muy grandes de puntos) y aquella terrestre (densidad muy distinta de puntos).

Al considerar las exigencias que los usuarios de orientación práctica, tales como los fotogrametristas y los geodestas, imponen a un sistema de programas, no deberían pasarse por alto las de los técnicos del proceso de datos. Estos últimos están interesados sobre todo en la comunicación con el sistema de programas. Con SCOP, el usuario está dialogando en un lenguaje de instrucciones que, por una parte, permita tanto el servicio por lotes como aquel interactivo y por otra un guiado tal como se lo conoce de la técnica "menue".

Para procesar los datos y sobre todo para detectar rápidamente combinaciones críticas de los mismos, se ponen a disposición del usuario los llamados útiles. Se trata por ejemplo de la salida de los datos existentes por puntos o por líneas, tanto en pantallas gráficas y aparatos de dibujo como en pantallas alfanuméricas y impresoras de líneas. Estas salidas a su vez sirven de base a las varias posibilidades de actualización para corregir los datos.

Se concluye la conferencia mencionando los interfaces más importantes del sistema de programa en cuestión con el fin de demostrar tanto la adaptación flexible a las varias configuraciones de computadores y de instrumentos de dibujo como las posibilidades de combinación con otros sistemas de programas. Se llama especialmente la atención sobre la transferencia a un banco de datos altimétricos del terreno de los datos originales y del MDT en forma de cuadrícula, ampliado por los cantos del terreno.

Prof. Dr.-Ing. K. Kraus,
Institut für Photogrammetrie an der Technischen Universität Wien,
Gußhausstrasse 27-29, A-1040 Wien