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THE SCOP DATA STRUCTURE FOR THE INTERSECTION AND CORRECTION OF DIGITAL TERRAIN MODELS

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1. Performance and further development of the SCOP system

Several years ago SCOP was introduced into practice as an universal system for processing digital terrain models (DTM). SCOP is used successfully for a number of different applications (Kraus et al., 1982) and consists of the following components:

1.1 Procedures for input, storage, representation, checking and correction of the acquired data. The data are describing the terrain form and can be composed of irregularly dispersed points, profiles, grids and additional lines (break lines, form lines, excluded areas).

1.2 Procedures for the conversion of the data into a standardized form suitable for all subsequent applications. They include the interpolation and storage of a rectangular grid of points and of the additional lines.

1.3 Files which are generated by the procedures of 1.2. Their organization is called the "DTM data structure". Each of these DTM files describes the terrain surface for a limited area.

1.4 Procedures which start from the DTM files and permit the following computations:

1.4.1 derivation of single terrain heights
1.4.2 derivation of vertical profiles
1.4.3 derivation of contour lines
1.4.4 derivation of digital slope models and slope maps

The practical use of SCOP has turned out a number of additional user requirements. Therefore, the system has been extended by the following components during the past two years. Their development is mostly completed.

1.5.1 Correction of the DTM files including the possibility of keeping available several versions of the terrain surface (e. g. before and after a construction project). Only the changed DTM parts have to be stored several times.

1.5.2 Intersection of two terrain surfaces of the same planimetric position, e. g. for volume computations.

1.5.3 Derivation of perspective representations of the terrain surface (including break lines etc.) and of visibility maps for any view point.

1.5.4 Interfaces for a fast and comfortable DTM access from any other software system.

2. An efficient data structure for the extended DTM applications

The DTM data structure of SCOP is shown in figure 1.

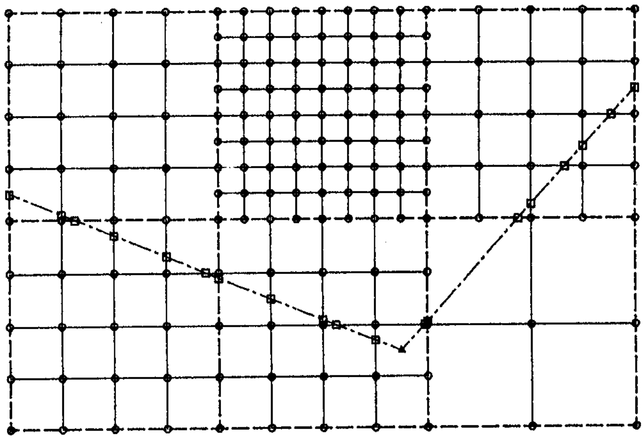


Fig. 1: The SCOP DTM structure

For a rectangular area the heights of the model points of a rectangular grid are stored as well as the additional break lines, form lines, spot heights and border lines (excluded areas). The DTM area is subdivided into rectangles of constant size. These rectangles are called computing units (CU).

The computing units are the records of the DTM data structure. Unfortunately, these records have different lenghts because of the varying grid size (Köstli, Wild 1984) and the additional lines. Therefore, only a sequential storage was used for a long time.

The original DTM applications (see 1.4) could be performed in this way without shortcomings although the records could only be processed in the same sequence as they were stored. However, an extension of a DTM system by the new components of 1.5 can only be efficient if any computing unit can be read at any time with a short access time.

This requirement has led to a data structure with direct access to data blocks of constant size (random DTM). The CU-records are stored sequentially into these blocks. The last CU of a block is continued in the following block (see fig. 2).

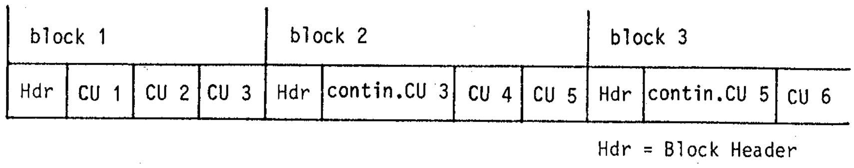


Fig. 2: DTM data blocks

The number of the first complete CU of a data block is stored in an index block (see fig. 3). In addition, the index block contains information about the minimum and maximum z-values and about the existence of spot heights and line information.

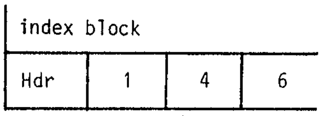


Fig. 3: DTM index block

If the index block is filled up the program automatically switches over to a hierarchical index (see fig. 4).

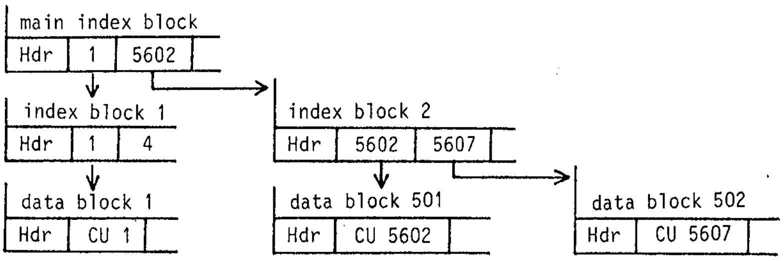


Fig. 4: Index hierarchy

An important aspect of the random DTM are the DTM correction facilities. Corrected DTM parts are stored into correction sets which can consist of several CUs. The actual correction sets are defined by pointers in the CU records.

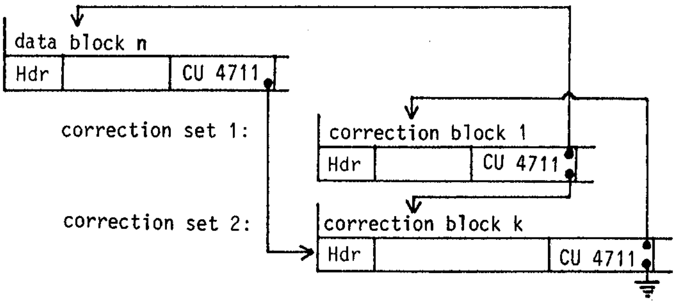


Fig. 5: DTM corrections

Correction sets can be deactivated and reactivated. If correction set 2 is deactivated in fig. 5, the pointer in CU 4711 of the data block indicates the correction block 1.

At first sight, the use of such correction blocks seems to be a waste of disc storage, because a multiple storage of the corrected CUs is necessary. On the other hand, the deactivation and reactivation of correction sets allows an access to several versions of a DTM with a multiple storage of only the corrected DTM parts.

The efficiency of this data structure mainly depends on the number of accesses to the disc (about 30 msec. per access) per "randomly" read CU. For small and medium size DTM areas (up to 100 000 grid points) one index block is sufficient which normally remains in the memory. For reading the data block one access or, in case of a block overflow, two accesses are necessary. In case of DTM corrections as well as for big DTMs one more access is needed, at the most.

These are estimations for the most unfavorable case. If a DTM application program works in a local part of a DTM, the DTM data are in most cases already in the memory. Therefore, only the interpolation of the terrain heights is necessary which is much faster than a disc access.

3. The software realization of the DTM access

The software interface for the use of the DTM data structure is split in two levels (see fig. 6).

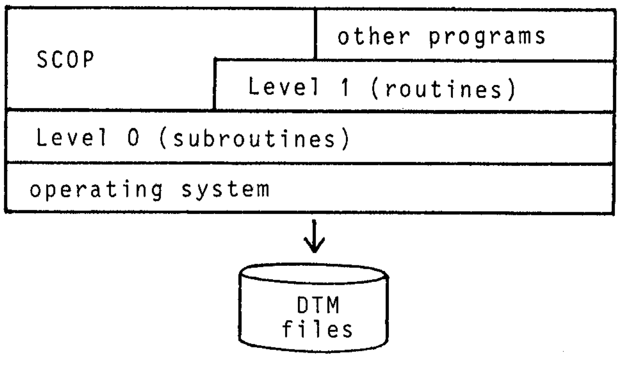


Fig. 6: Access to the SCOP DTM

The lower level (level 0) essentially consists of the following subroutine calls for reading and writing DTM data blocks:

- sequential write for building up the DTM file
- random write for DTM corrections
- random read for new DTM applications
- sequential read for "sequential" DTM applications.

Level 0 is used by the SCOP programs and by level 1.

In level 1 routines are made available for the access of any SCOP independent program to the DTM files. Level 1 can control a big number of DTM files at the same time, if only their file names resp. file numbers have been defined. The calling program delivers x and y coordinates. The assignment to the DTM files is done by the level 1 routines, which particularly include:

- the interpolation of single terrain heights
- the interpolation of vertical profiles
- the interpolation of height grids
- the extraction of lines and special points from the DTM

4. Application of the new DTM data structure

As mentioned in chapter 2, there is a number of new DTM applications which require a random structure of the DTM files. A sequential DTM storage which was mostly in use up to now, is not sufficient for those applications, especially in case of large terrain models. The realization of some of these new applications in the program system SCOP is demonstrated in the following.

4.1 Correction of digital terrain models

With most of the existing DTM programs, it is necessary to generate the complete DTM again, even if only a small DTM part has to be corrected. On the other hand, the new SCOP DTM data structure allows a local DTM correction according to chapter 2, which is of interest particularly for the following cases:

4.1.1 Revision of national DTMs

National DTMs are presently built-up in several countries (e.g. Sigle, 1984). Their storage can only be efficient if a later revision is guaranteed.

A DTM revision is requested if building projects have changed the terrain form, or if the data acquisition has originally been of low accuracy and is implemented later by a more accurate data acquisition for parts of the DTM. For this case the SCOP DTM is especially suited because of its variable grid interval (Köstli/Wild, 1984) which allows a denser DTM grid for the more accurate parts. Therefore, the local grid interval can be used to characterize the local DTM quality.

4.1.2 Terrain models for construction projects

For the planning of contruction projects DTMs are mainly used for the computation of earth volumes. Besides that, the future terrain can be shown in perspective, profile or contour representations in order to demonstrate the changes or to support the construction.

For the solution of these tasks a DTM of the planned terrain is generated by an intersection of planned break lines or terrain slopes with the existing DTM, and by replacing the changed DTM parts. The corrected DTM can then be used by any SCOP application program.

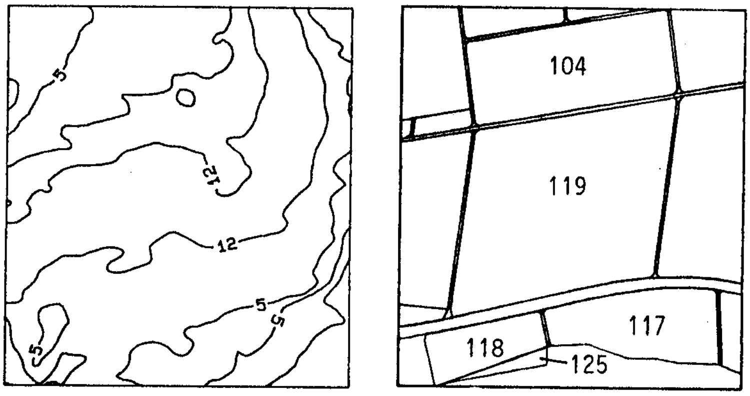
4.2 Intersection of digital terrain models

For the intersection of differently structured DTMs a new SCOP module was developed, for which the input data can consist of raster data (e. g. height models, slope models) as well as of vector data (e. g. parcel boundaries). Different intersection results can be produced such as differences, volumes, intersection areas, mean values or classifications. In the following, 3 typical DTM intersection problems are described.

4.2.1 Intersection of raster and vector data

In an example from the field of land consolidation a digital slope model (raster data) is intersected with digitized parcel boundaries (vector data). The intersection purpose is the determination of areas into which the parcels are subdivided by different slope classes. The result is used for the evaluation of farm land.

The parcels are given as closed polygons. For each computing unit of the slope model, which is partly situated inside a polygon, the slope grid is subdivided into slope classes for which the areas inside the polygon are computed. The lines of the slope model (break lines, border lines) are considered stricly.



slope map

parcel boundaries

	slope [%]		
	< 5	5-12	>12
parcel	area [m²]		
104	5249	2567	882
117	1712	2124	273
118	315	2028	285
119	49	8437	9556
125	201	252	10

Fig. 7: Intersection of a digital slope model and parcel boundaries

Another possible solution which would use isolines, derived from the digital slope model, for an intersection with the parcel boundaries would be considerably less efficient.

4.2.2 Intersection of two raster models

The most frequent application of an intersection of raster data is the determination of earth volumes. The input data for the SCOP intersection module are two digital elevation models with the structure of the SCOP DTM. The DTMs may have different grid intervals and different line information.

At first, a model of the height differences is built-up, for which the structure of one of the DTMs is used. The difference model contains break lines and form lines of both DTMs. Their heights in the second model are interpolated from the surrounding DTM grid.

The volumes for cuts and fills are then computed with the program for the intersection of raster and vector data (see 4.2.1), for which the limits of the intersection area and the intersection lines (height difference 0) are used as vector data.

4.2.3 Intersection of vector data

An example for the intersection of vector data is the determination of soil classes for the parcels of a land consolidation project. The parcel boundaries and the boundaries of the soil classes must have been digitized.

The most obvious solution for this problem is a direct intersection of polygons (Stanger, 1982). In the SCOP intersection module another method was selected. At first, one of the vector models is transformed into a raster model and then intersected with the other vector model according to 4.2.1.

4.3 Perspective DTM representation

The new DTM structure with a direct access to small parts of a DTM is the main precondition for an efficient computation of perspective views of the terrain. This is particularly important with regard to a strict consideration of the representation and visibility of break lines and excluded areas (Kager, 1984).

The number of disc accesses could be considerably reduced by a determination of the visibility of a computing unit using the minimum and maximum z-values of the DTM data blocks which are stored in the DTM index block. Therefore, an access to the DTM files is not necessary for invisible computing units.

The same aspects are valid for the derivation of visibility maps in which the visible terrain parts are plotted for a certain view point.

4.4 Use of the SCOP DTM in other systems

With the direct access to small DTM parts, a DTM can now be used on-line by different systems. For this purpose the DTM access routines (see chapter 3) are made available which allow a DTM access from SCOP independent systems.

From a great number of applications some examples in the fields of photogrammetry and mapping are mentioned in the following:

- direct control of orthoprojectors

  Analytical orthoprojectors could directly use the DTM to get the required height information. A preparation of suitable terrain profiles is no longer necessary.

- analytical mono-plotters

  The DTM could be used for mapping from only one aerial photograph. The terrain heights would be continuously called from the DTM by a loop program using level 1 routines.

- interactive graphical system

  Together with interactive graphical systems often DTMs are requested to add the third dimension to the two-dimensional data base. This is possible now by using the access routines for the derivation of single heights or profiles defined in planimetry at the graphics work station.

5. Importance of the presented developments

By the presented developments the SCOP system was considerably extended with regard to a general use of digital terrain models (see fig. 10).

The direct access DTM structure can handle new DTM applications, not only by new SCOP modules but also by SCOP independent computer programs.

Together with the DTM correction facilities the new DTM data structure is the most important requirement for an efficient generation and revision of national DTMs.

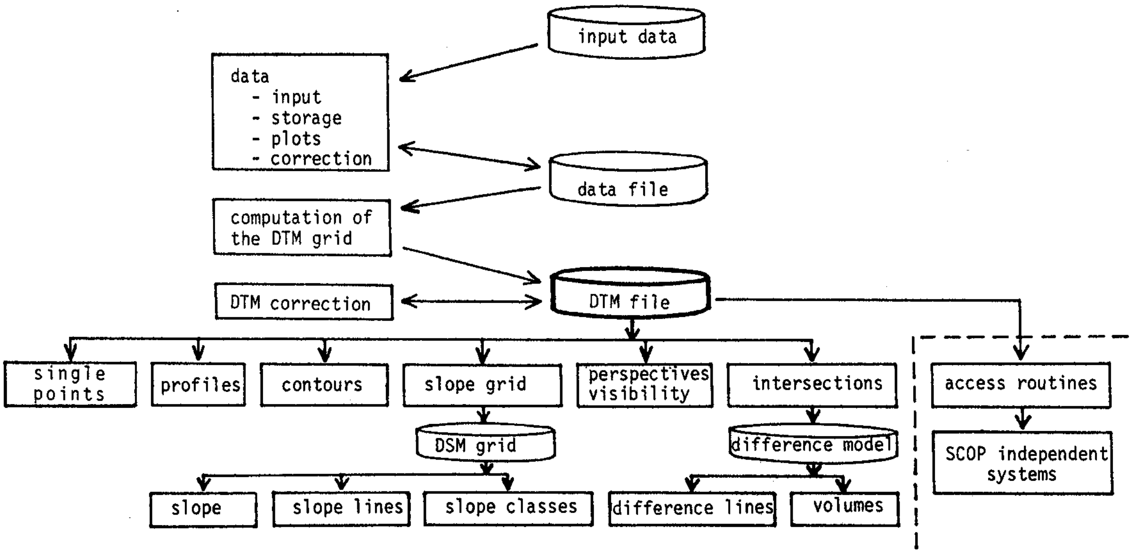


Fig. 10: Data flow in the DTM system SCOP

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/1/ Ackermann, F. (1985): Data processing aspects of digital elevation models, Conference of Southern African Surveyors, Durban, South Africa

/2/ Kager, H. (1984): DTM - Displayed perspectively, pres. paper, Comm. III, ISPRS Congress, Rio de Janeiro

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/5/ Sigle, M. (1984): A digital elevation model for the State of Baden-Württemberg, pres. paper, Comm. III, ISPRS Congress, Rio de Janeiro

/6/ Stanger, W. (1982): Ein digitales Geländemodell und einige Anwendungsmöglichkeiten im Bereich der Flurbereinigung, DGK Reihe C, Nr. 273.

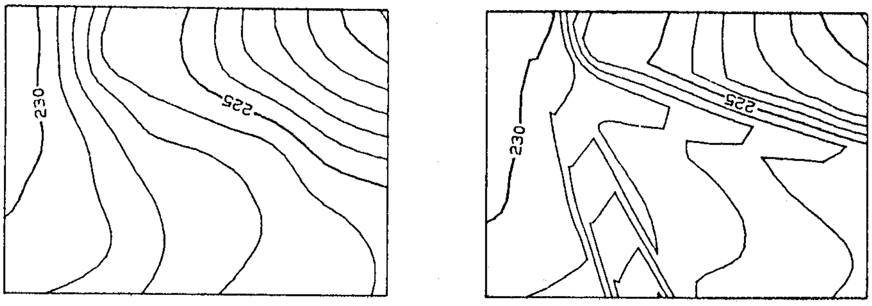
Abstract

Increasing requirements and new applications for digital terrain models have led to the development of a new DTM data structure (random DTM) for the program package SCOP. The new data structure allows a direct access to small DTM sections. This is mainly profitable to corrections, intersections and perspective representations of digital terrain models. In addition, access routines are made available which enable an efficient use of the DTM by SCOP independent application programs.

DIE SCOP-DATENSTRUKTUR ZUR VERSCHNEIDUNG UND KORREKTUR VON GELÄNDEMODELLEN

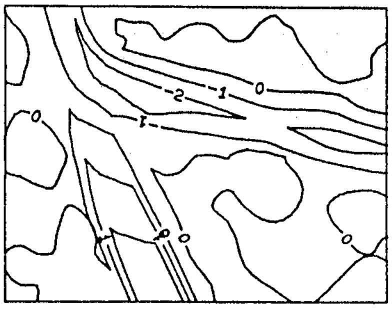
Zusammenfassung

Erhöhte Anforderungen an die Leistungsfähigkeit digitaler Geländemodelle und neue Anwendungsbereiche führten für das Programmsystem SCOP zur Entwicklung einer neuen DGM-Datenstruktur (Random-DGM) mit direktem Zugriff auf kleine DGM-Ausschnitte. Die neue Datenstruktur erleichtert vor allem die Korrektur, Verschneidung und Perspektivdarstellung digitaler Geländemodelle. Zusätzlich werden Zugriffsroutinen bereitgestellt, die für SCOP-fremde Anwendungsprogramme eine effiziente Nutzung des DGM zulassen.



original terrain

altered terrain



height differences

	fills	cuts
area	6053	4886
volume	156.1	157.3

Fig. 8: Volume determination from two DTMs

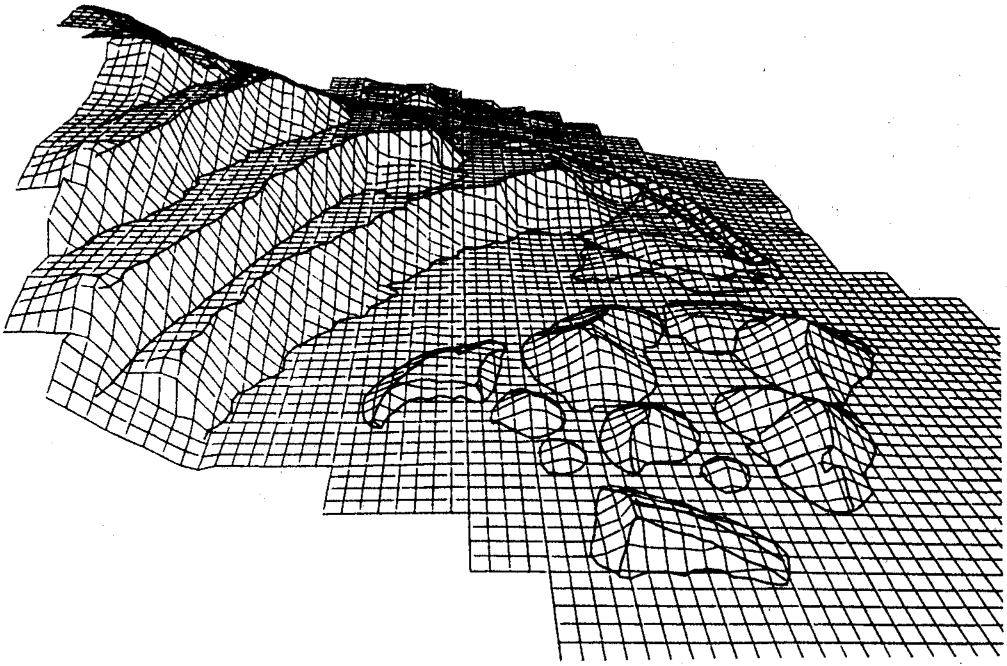


Fig. 9: Perspective DTM representation (plotted by the Photogrammetric Institute of the Technical University, Vienna)

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