THE RANDOM ACCESS DATA STRUCTURE OF THE DTM PROGRAM SCOP

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Abstract
For the program package SCOP a new DTM data structure was developed which allows a direct access to small DTM sections. Its development was the precondition for the realization of some new DTM applications and for the generation and revision of national DTM's. In addition to some examples for these new applications, the paper describes access routines for a fast DTM utilization by any user program.

1. Preliminary remarks
For a number of years the interpolation methods have been in the foreground of discussions about digital terrain models. Some different methods have emerged as basis of sophisticated programs which have been found out to have more or less sophisticated performance and performance.

In the meantime these discussions have been replaced by a even more important problem, the data processing aspects of digital terrain models (Ackermann, 1985). Especially for the program package SCOP great efforts have been undertaken, during the past 5 years, to proceed from a DTM program to a DTM system.

2. Review of the SCOP system
SCOP is a general program system for the generation and application of digital terrain models (DTM). It has been developed in several steps since about 1972 in cooperation of the Forschungsinstitut für Luftbildtechnik GmbH, Stuttgart (Prof. Ackermann) and the Photogrammetric Institute of the Technical University Vienna (Prof. Kraus).

In the beginning the immediate purpose of SCOP was the derivation of contours from photogrammetric profiles. With increasing user requirements some new DTM application programs (derivation of profiles, digital slope models and slope maps) have been developed until 1981. In the same period a strict consideration of break lines, form lines and excluded areas was realized.

Since 1985 a new level of performance has been reached by the development of a direct access data structure for the DTM. The DTM is now the central component of the system (see fig. 1). Its new data structure has been the main precondition for the development of new DTM application programs (DTM intersections and perspective DTM representations) and for a general use of the DTM.
fig. 1: Data flow in the DTM system SCOP

In the meantime SCOP is used by a number of organizations and on a number of different computers mainly in the following fields:
- generation of national DTM's
- road construction (profiles and volumes)
- land consolidation (slope maps and DTM intersections)
- orthoprojection
- contour derivation

3. The data structure of the SCOP DTM

For the acquired terrain data which may be dispersed arbitrarily, a rectangular grid of terrain heights is interpolated and stored into rectangular computing units (see fig. 2). By using a variable grid interval (Köstli/Wild, 1984) the grid density can be adapted to the density of the acquired points and to the terrain roughness.

fig. 2: SCOP DTM structure
A main feature of the system is that all break lines, border lines, form lines and spot heights form essential constituents of the DTM, in addition to the grid points. For each line its acquired points and its intersections with the grid lines are stored. This enables a strict consideration of the most important terrain form elements during the DTM interpolation as well as during the DTM applications.

The computing units (CU) constitute also the records of the DTM data structure, including break lines, border lines, etc.. Unfortunately these records have different lengths. Therefore, a sequential DTM data storage was used for a long time. On the other hand a very fast access to any CU is necessary for an efficient realization of the new DTM applications described in the chapters 3, 4 and 5.

For that reason a new DTM data structure with direct access to data blocks of constant length was developed. The CU records are stored sequentially into these data blocks. The last CU of a block is continued in the next data block. The number of the first complete CU of a data block is stored in an index block. For large DTM the program switches over to a hierarchical index (see fig. 3).

![Diagram of index hierarchy of the SCOP DTM](image)

The described DTM data structure is extremely efficient. The maximum number of disc accesses for any CU of the DTM is 2 for small DTM and 3 for large DTM with more than 100,000 grid points. Therefore, any CU is available in less than 0.1 seconds.

A very important aspect of the new DTM data structure is the easy correction or updating of existing DTM. Corrected DTM parts are stored into correction sets which can consist of several CUs. Such correction sets are activated by pointers in the DTM data blocks and can be deactivated and reactivated. Therefore, several versions of the terrain can be stored in the same DTM.

The main advantage of these correction facilities is the fact that for the correction of large DTM only the altered terrain parts have to be interpolated again.
4. Realization of the DTM access

The interface for the DTM access consists of two levels (see fig. 4). The lower level (level 0) includes calls for SCOP subroutines for sequential and random reading and writing of data blocks. Level 0 is used by the DTM application programs of SCOP and by the routines of level 1.

In level 1 routines are made available for a comfortable access to the DTM files by any SCOP independent program. The routines of level 1 can control a large number of DTM files at the same time. The calling programs deliver x and y coordinates of the DTM coordinate system. The routines determine the respective DTM files and derive the heights of single points, profiles or grids from the DTM.

![Diagram of DTM access](image)

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fig. 4.: Access to the SCOP DTM
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For the routines of level 1 a great number of applications can be imagined. Some examples in the fields of photogrammetry and mapping are:

- **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 the level 1 routines.

- **interactive graphical systems**
  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. Storage and revision of national DTMs

National DTMs with millions of terrain heights are presently built up in several countries. They are increasingly requested for a number of different applications.

For the storage of national DTMs the SCOP data structure is particularly suited because of its following features:

- The DTM generation software can generate very large DTMs of more than a million grid points in one run. The amount of data is restricted mainly by the disc capacity.
- The routines for the direct DTM access permit a very fast and comfortable use of national DTMs for any application.
- A national DTM can consist of a number of DTM files which can be accessed at the same time.
- The DTM correction facilities enable a revision of DTM parts. This feature is of great importance in case of changed terrain forms or of a more accurate new data acquisition.
- The DTM can have a variable grid interval and can therefore contain terrain data of different quality. The local grid interval can be used to characterize the local quality.

An example for a national DTM generated with SCOP is the DTM of Baden-Wuerttemberg (Fed. Rep. of Germany) (Sigle, 1984), which is presently established for the state survey authority. For an area of 36 000 km² a 50 m grid is interpolated from digitized GZ1 orthophoto profiles of 80 m profile distance. The DTM is subdivided into about 75 DTM files according to the sheet format of the topographic map 1:50 000. Some details about this DTM are shown in table 1.

The main purpose of the DTM is its use for the production of orthophotos for the revision of topographic maps. On the other hand the state survey authority has already delivered DTM parts to other organizations for various applications.

<table>
<thead>
<tr>
<th>DTM area</th>
<th>36 000 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>grid interval</td>
<td>50 m</td>
</tr>
<tr>
<td>number of grid points</td>
<td>16 000 000</td>
</tr>
<tr>
<td>storage capacity</td>
<td>120 MB</td>
</tr>
<tr>
<td>number of DTM files</td>
<td>75</td>
</tr>
<tr>
<td>height accuracy</td>
<td>1.5 - 5 m</td>
</tr>
<tr>
<td>DTM generation for one DTM file:</td>
<td></td>
</tr>
<tr>
<td>number of digitized profile points</td>
<td>270 000</td>
</tr>
<tr>
<td>number of grid points</td>
<td>279 000</td>
</tr>
<tr>
<td>CPU time (Harris H 100)</td>
<td>40 sec</td>
</tr>
<tr>
<td>disc capacity required during DTM generation</td>
<td>40 MB</td>
</tr>
</tbody>
</table>

Table 1: DTM Baden-Wuerttemberg
6. New DTM application programs

The main reasons for the development of the new DTM data structure have been some new DTM applications which could only be realized efficiently by having a direct access to local parts of a large DTM. For some of the new applications, programs have been developed each of which with strict consideration of break lines, form lines and excluded areas.

6.1 Volume determination

The SCOP module INTERSECT (Köstli/Sigle, 1985) was developed for the intersection of two superimposed digital terrain models. One application is the computation of earth volumes. The input data are two DTMs which can have different structure (different grid interval, different break lines, form lines and border lines). At first, a common DTM structure for both models is built up by interpolating z-values from model B for the DTM points of model A. Afterwards, a digital model of the height differences is derived with the same structure as the DTMs. The difference model can now be used for the computation of cuts and fills and for the derivation of difference isolines. An example is shown in figure 5.

![original terrain](image1)

![altered terrain](image2)

![height differences](image3)

**fig. 5: Volume determination from digital terrain models**

With these methods, hidden cuts and fills can be determined.

7. Conclusion

By the use of a combination of computers, the detailed DTMs can be stored and used for further processing. The system provides an intuitive way for designing and simulating. Together with the digital structure, the program was the first step towards the development of a total digital information system for soil and agricultural utilization.
Beside the intersection of raster data INTERSECT can also be used for the intersection of vector data with a raster model. An example is the determination of slope classes for parcels of farmland which are used for land evaluation in land consolidation projects. The input data for this application are a digital slope model derived from a DTM on the one hand and the digitized parcel boundaries on the other hand.

6.2 Perspective DTM representation

The module PERSPECT (Kager, 1984) delivers perspective views of the DTM grid from selectable viewpoints. Hidden areas are strictly considered as well as break lines and excluded areas. An example plotted by the Photogrammetric Institute of the Technical University Vienna is shown in figure 6.

![Perspective DTM representation](image)

**fig. 6: Perspective DTM representation**

With the same module visibility maps can be derived in which the hidden areas are plotted.

7. Conclusion

By the presented developments the SCOP system was considerably extended with regard to a general use of digital terrain models. The direct access DTM structure enables 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.
Reference


