SOFTWARE FOR MANAGING COUNTRY-WIDE DIGITAL ELEVATION DATA

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ABSTRACT

Some principle aspects of managing country-wide digital elevation data are summarized at the beginning, including proper methods of data compilation, coding and structuring of topographic data, and processing and usage of these data. This applies both for primary topographic data (original data) and for derived products. Based on this introductory notes a software package (SCOP.TDM) is presented, which has been developed at the Institute for Photogrammetry and Remote Sensing at the Vienna University of Technology, and serves for storage, administration and archiving of country-wide topographic data.
The main topics concentrate on using a relational data base system, which has been extended with functionality to store topological elements (AREA, LINE, POINT, WINDOW) and to operate on them with topological operators (.X. , .<. , ...). Additional important aspects are flexible support of data formats for importing (IMPORT) and exporting (EXPORT) original data as well as derived products, integration of additional non-geometric data properties (accuracy, data compilation method, authorized users of the data, ...), management of huge amounts of topographic data, and individual data selection by formulating complex conditions.
Finally some practical experiences from the Federal Office for Topography (Switzerland) and the Federal Office for Metrology and Surveying (Austria) about using SCOP.TDM are given.

KURZFASSUNG

Einleitend werden die Grundlagen zur Verwaltung landesweiter Geländehöhendaten zusammengestellt. Das bezieht sich sowohl auf Basisdaten (Originaldaten) als auch auf daraus abgeleitete Produkte. Dabei werden die Datenerfassungsmethoden, die Codierung und Strukturierung der Daten, ihre Verarbeitung und deren Nutzungsmöglichkeiten beleuchtet. Auf dieser Basis wird eine Softwarelösung (SCOP.TDM) des Instituts für Photogrammetrie und Fernerkundung an der Technischen Universität Wien vorgestellt, mit der landesweite Geländehöhendaten verwaltet werden können.
Schwerpunktmäßig sind die Verwendung einer um topologische Elemente (AREA, LINE, POINT, WINDOW) und topologische Operatoren (.X. , .<. , ...) erweiterten relationalen Datenbank (TOPDB), die flexible Unterstützung verschiedener Datenformate bei der Datenübernahme (IMPORT) und Datenabgabe (EXPORT) von Originalhöhendaten und daraus abgeleiteten Produkten, die Einbringung von nicht-geometrischer Datenbeschreibungsinformation (z.B. Genauigkeit, Datenerfassungsmethode, Nutzungsberechtigte, ...), die effiziente blattschnittfreie Verwaltung größter Datenmengen und die Selektion und direkte Nutzbarkeit der Daten durch Geländemodellapplikationen zu nennen.
Schließlich wird noch kurz über den praktischen Einsatz der vorgestellten Lösung beim Bundesamt für Landestopographie (Schweiz) und beim Bundesamt für Eich- und Vermessungswesen (Österreich) berichtet.

1. INITIAL SITUATION

National land surveying authorities or comparable institutions of many countries have already built up DTMs to cover the entire territory of their country or are at least working to complete the creation of a country-wide DTM. Some other countries are already engaged in quality improvement of their existing basic DTM. Several different methods are used to compile the data. Accuracy varies within the range of a few decimeters and some meters. Because lots of man power, financial and technical resources have been invested to collect these topographic data, it is quite proper to claim maximum benefit from exploiting this data pool. For this reason it is absolutely necessary to provide best conditions for DTM production by an efficient and well-suited data organization offered by an appropriate software solution.

The Institute for Photogrammetry and Remote Sensing at the Vienna University of Technology has been engaged in DTM technology since many years in the field of research and education but also in developing DTM applications. Examples are SORA (software for the digitally controlled production of analog orthophotos; Loitsch, Otepka, 1976), TOPIAS (software for archiving topographic data; Loitsch, Kraus, 1986), and SCOP (software for creating, maintaining and applying DTMs; IPF, 1994). Starting from these experiences a new product (SCOP.TDM) for storing, managing and archiving topographic data and derived products has been developed and will be presented in this paper.

2. DATA COMPILATION

Several methods are used by the national authorities to compile the topographic data. A few typical examples from national surveying authorities will be given.

The Federal Office of Metrology and Surveying (Bundesamt für Eich- und Vermessungswesen) in Austria is doing data compilation by means of photogrammetry. They started in 1976 on analog stereo plotters by measuring profiles in aerial images with scale 1:30000. About ten years later the method changed to compiling profiles, breaklines, formlines and spot heights on analytical instruments from image material with scale 1:15000. The complete data set consists of about 80 millions of points.

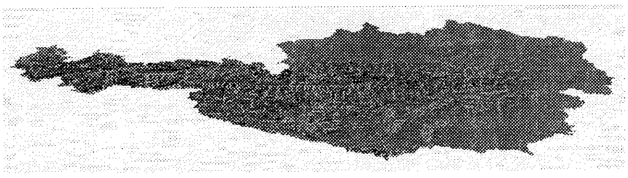

Figure 1: DTM from Austria (250 m x 250 m grid)
(Data: Institute for Photogrammetry and Remote Sensing, TU Vienna)

In Switzerland the Federal Office for Topography (Bundesamt für Landestopographie) uses a completely different approach. Topographic maps with scale 1:25000 are scanned and contourlines, lakes and spot height points are extracted semi-automatically.

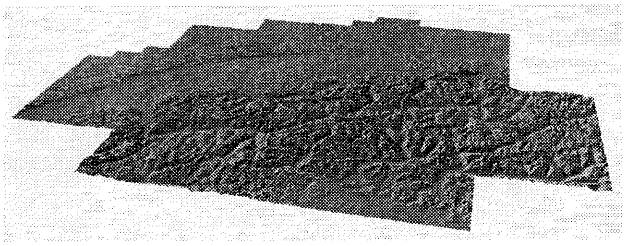

Figure 2: DTM of Switzerland (250 m x 250 m grid)
(Data: RIMINI Model, Federal Office for Topography)

The situation at the Bavarian Office for Surveying (Bayerisches Landesvermessungsamt) is very similar to Austria. An essential difference is, that they are involving private companies for data compilation.

Practically any method (manual digitizing of contour maps, tacheometric surveys, ...) can be used, which can deliver data economically, as long as the results are 3-dimensional and accuracy demands are fulfilled.

3. CODING AND STRUCTURING OF TOPOGRAPHIC DATA

Topographic data are organized either as line objects (ridge, dam, river, ...) single objects (spot heights, ...) or groups of point objects (photogrammetrically compiled grid data, ...). The meaning of an object is described by assigning feature code information to it.

In practice two different approaches can be selected. One way is to code the data depending on geomorphological criteria (breakline, spot height, ...) or on how to influence different interpolation methods when calculating DTMs, while the other method is to assign really the actual meaning of the object (brook, dam, slope, ...). In consideration of long-term administration and usage of the data, it is most desirable to keep as much coding information as possible.

4. APPLICATION OF TOPOGRAPHIC DATA

Of course topographic data are used to manage internal projects of surveying authorities or to work on behalf of other institutions. But an increasing demand emerges from private customers too. As long as the data are used only for internal purposes, it is rather easy to adapt data organization to a few typical production processes. Much more requirements have to be satisfied when executing requests from customers because of the variety of DTM products, data exchange formats and also because of strict deadlines. To enable efficient project management, all the necessary technical resources must be applicable in a highly flexible manner.

5. SOFTWARE SOLUTION

Based on these previously sketched general remarks and topics a concept for a software package (SCOP.TDM) has been designed and finally implemented at the Institute for Photogrammetry and Remote Sensing at the Vienna University of Technology. Although this paper deals mainly with managing country-wide topographic data, most parts of it are applicable for private surveying companies too. In this case more the inhomogeneity of the data is of importance than the huge amount data.

5.1 Strategy

The concept follows two main goals. Naturally most important is an efficient long-term storage and archiving of topographic data. This not only concerns geometry (coordinates) and coding, but also information about other data characteristics (accuracy, compilation method, authorized data users, ...), because these additional properties allow for good individual data selection. On the other hand it is necessary to provide a qualified basis for DTM application programs. Frequency of data access during operating on an actual project is much higher than access to an archive. This in any case enforces to store the topographic data permanently on the computers hard disk during work on a DTM project. But for archiving purposes also removable external direct access media should be considered as an acceptable alternative. In some situations there may be no clear distinction between project and archive phase when most parts of the data are used nearly all the time. So it should be the users decision to choose proper data organization. Finally another important topic is compatibility with other DTM packages by flexibly supporting different data formats for data import and export.

5.2 Data Base Manipulation System

A data base manipulation system (TOPDB) has been completely developed at the Institute for Photogrammetry and Remote Sensing at the Vienna University of Technology to store, manage and archive topographic data (Loitsch, Molnar, 1991). It is a relational data base system, that has been extended by geometric/topological elements and appropriate geometric/topological operators to handle these elements.

Topological data types include AREA (closed polyline), LINE (open polyline), POINT (single point) and WINDOW (rectangle parallel to coordinate system axis). Additional operators (.X. , .<. , .>. , ...) allow for intersection and selection of geometric/topological data sets.

Communication between TOPDB and an application is done by a data base language called „TOPSQL". Its current functionality is on the one hand a subset of ANSI-SQL but on the other hand an extension regarding the geometric/topological data types and operators.

A typical data selection could be to extract all data from a specified table, which are at least partly inside a given area, which have an accuracy for heights better than 30 cm and have been compiled later than 1985-10-20. These query can be formulated by using TOPSQL.

```
SELECT * FROM DHMDATA
 WHERE (COORDINATES .X. AREA (10000 50000
                              15000 60000
                              20000 40000)
   AND (ZACCURACY < 0.30)
   AND (COMPILEDATE > 20.10.1985);
```

5.3 Table System

For storing, managing and archiving topographic data a complex system of tables is used. Several types of different tables have been defined to describe the structure of a table and the data type for each column of the table. In SCOP.TDM about two dozens of different table types are involved. Most of them serve only for internal organizational or summary purposes, but a few of them are of interest for the user. This includes tables for storing topographic data, tables for controlling translation of coding information during data import and export and vocabulary tables.

5.3.1 Tables for Storage of Topographic Data: The most important tables are of type TDXYZTAB. Such tables are used to store and manage arbitrarily distributed topographic data. A data set in one of these tables corresponds to exactly one terrain object represented by a series of 3-dimensional coordinates and additional data properties. The full definition of a table of type TDXYZTAB is shown in table 1.

IDOBJ	INTEGER	UNIQUE	INDEX	NOT NULL	SYSNUM IDENTIFIER
DATAFORMAT	CHAR(16)		INDEX	NOT NULL	
AGGREGATE	CHAR(16)		INDEX	NOT NULL	
OBJECTNAME	CHAR(16)		INDEX	NOT NULL	
OBJECTTYPE	CHAR(16)		INDEX	NOT NULL	
COORDINATES	LINE		INDEX	NOT NULL	PERIOD(3) RESOLUTION(2,2,2)
FEATURECODE	CHAR(32)		INDEX	NULL	
STATUS	CHAR(16)		INDEX	NULL	
XYACCURACY	NUMBER(12.2)		INDEX	NULL	
ZACCURACY	NUMBER(12.2)		INDEX	NULL	
CREATOR	CHAR(32)		INDEX	NULL	
OWNER	CHAR(32)		INDEX	NULL	ARRAY
COMPILEMODE	CHAR(32)		INDEX	NULL	
PROPERTIES	CHAR(32)		INDEX	NULL	ARRAY
COMPILEDATE	DATE		INDEX	NULL	
COMPILETIME	TIME		INDEX	NULL	
INSERTDATE	DATE		INDEX	NOT NULL	
INSERTTIME	TIME		INDEX	NOT NULL	
UPDATEDATE	DATE		INDEX	NULL	
UPDATETIME	TIME		INDEX	NULL	

Table 1: Definition of Table Type TDXYZTAB

For each column the name of the column, the data type, indexing instructions and other attributes are listed. This definition includes a list of coordinates (COORDINATES), an object meaning (FEATURECODE), the type of an object (OBJECTTYPE), an object name (OBJECTNAME), the objects original data format (DATAFORMAT), information about accuracy in planimetry and height (XYACCURACY, ZACCURACY), the name of the organization responsible for data compilation (CREATOR), a list of authorized data users (OWNER), information about the compilation method (COMPILEMODE), a list of additional properties (PROPERTIES) and information about date and time of data compilation (COMPILEDATE, COMPILETIME).

5.3.2 Data Format Code Conversion Tables: Topographic data are read in from files organized according to commonly used data formats (WINPUT, DXF, ARC/INFO Generate, ...) and are stored in topographic data tables. This process is called „data import". The opposite operation is to extract data from topographic data tables and to write these data to files. This is called „data export".

In both cases it is necessary to translate coding information from the external data representation format to the native representation and vice versa. These translations are controlled by data format code conversion tables, which are set up by the user. The structure of a data format code conversion table depends on the individual data format. Table 2 gives an example for DXF. During the IMPORT process the coding pair for an object in DXF (LAYER, ENTITY) is mapped to a pair used in tables of type TDXYZTAB (FEATURECODE, OBJECTTYPE). When exporting data the reverse mapping is done.

IDCDXF	INTEGER	UNIQUE	INDEX	NOT NULL	SYSNUM IDENTIFIER
FEATURECODE	CHAR(32)		INDEX	NOT NULL	
OBJECTTYPE	CHAR(16)		INDEX	NOT NULL	
ENTITY	CHAR(12)		INDEX	NOT NULL	
LAYER	CHAR(32)		INDEX	NOT NULL	
COMMENT	STRING			NULL	

Table 2: Definition of Table Type CVDXFTAB

5.3.3 Vocabulary Tables: On many occasions assignment of names or other terms is necessary when using SCOP.TDM. Examples are names of authorized data users, names of coordinate systems or feature codes. To ensure a systematic usage of such names, a global name space can be set up in vocabulary tables as basis for checking user input. Furthermore consistency in spelling and using names is advantageous when specifying conditions for data selection.

5.4 Topographic Data Market and Archive

All tables for storing topographic data together with meta-information and additional organizational and summary tables are placed in a disk area, which is called „Topographic Data Market". This area is permanently available on the disk. It is the market place for all activities concerning data import and data export. DTM application programs may access these data too.

Long-term storage and archiving of topographic data is done in the „Topographic Data Archive". Topographic data can either be copied or moved from the data market to the data archive .

Both the topographic data market and the archive consist of two groups of tables. Some organizational and summary tables, which are rather small, are used to maintain topographic data tables, which may consume lots of disk space depending on the amount of topographic data to handle. Organizational and summary tables for the market and archive are stored always on the hard disk. They can be used in many cases to retrieve general information about the data without having to search in the large topographic data tables. While the topographic data tables of the market are also available permanently on the disk, they may be stored on external storage media for the archive. These media must allow for direct access like hard disks. Examples are magneto-optical disks or removable disk cartridges. Tapes can only be used for backup purposes („disaster prevention").

5.5 Derived Products Market

By using primary data as input to DTM application programs several types of products can be derived. Naturally the most important products are interpolated grids, but also calculated slope models or contour lines are typical derived products. A decision has to be made by the user, whether it is necessary to create these derived products and to store them permanently or it is more convenient to re-create them from the primary topographic data on demand. The answer depends mainly on the production environment of the user and the frequency of customers orders.

Currently SCOP.TDM supports management of regular grid data for different data formats as well as the hybrid DTM structure of SCOP (Köstli, Sigle, 1986).

The strategies for managing derived products in the „Derived Products Market" are quite analogous to managing primary data in the „Topographic Data Market". Again organizational and summary tables are used to allow for answering general queries about the available products. But an essential difference to managing primary topographic data is that derived products are stored in the data format they have been created. They are not stored in TOPDB tables. This method has some advantages. There is not involved any conversion process and therefore no loss of information occurs. Furthermore these products can still be accessed by DTM application programs. Finally products can be managed, that are not coming directly from a SCOP production environment.

The export process for derived products is much more complex than for exporting topographic data, because derived products may be stored in different data formats and may have different grid intervals. It is possible to deliver derived products according to a user specified area of interest and a selected grid interval in any requested and supported data format. All necessary actions for merging together individual derived products for the selected final product are performed automatically.

A completely different problem concerning derived products is the updating process in the case of modified primary topographic data, from which the products have been created. Precautions have been taken to allow for recognizing the necessity to update derived products in such cases.

6. PRACTICAL EXPERIENCES

After an experimental phase of a few months the Federal Office for Topography in Switzerland decided at the end of 1994 to integrate SCOP.TDM into their DTM production environment. The software system has been installed on a UNIX platform (RS/6000; AIX).

Both the so-called „Basismodell" (Basic Model), which consists of contourlines, lakes and spot heights derived from the topographic map 1:25000, and the so-called „Matrixmodell" (Matrix Model) representing a regular grid with a grid interval of 25 meters are managed by SCOP.TDM. Primary data are stored in about 250 topographic data tables. On an average each table contains about 200000 points and has a size of about 3 MB. This organization results more from practical experience than from theoretical models. For storing a single point 18 bytes are used. The total disk space occupied by all the topographic data tables and the appropriate information and summary tables is less than 1 GB.

The Austrian Federal Office for Metrology and Surveying uses SCOP.TDM also on a UNIX system (HP9000/715; HP-UX). The primary data have been compiled photogrammetrically (profiles, breaklines, formlines, spot heights) and consist of about 80 millions of points. The size of the topographic data market is about 2.5 GB.

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