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PHOCUS FOR CARTOGRAPHIC APPLICATIONS

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1. INTRODUCTION

A Geographic Information System (GIS) is of particular benefit when its data is utilized for a wide variety of applications including the production of different map types.

What preparations are involved in the compilation of a new type of map?
Depending on the intended purpose of the map, a suitable **scale**, **sheet line system** and **graphic code** as well as a **map frame** and **legend** must be selected. Moreover, the **map contents** need to be defined and, if necessary, the relevant part of the entire data base must be selected for representation.
The smaller the scale - from about 1:5000 downward - the more comprehensive the rules that must be set up for **cartographic generalization** and the greater their impact. In this respect, the same preparations are required both for conventional and computer-supported map production.

Commercial GIS products provide for all these procedures, with one exception:
computer-supported, cartographic generalization is only available to a very limited extent. This gap is now being filled by PHOCUS, as will be shown in the following comments.

2. OBJECT INFORMATION AND GRAPHIC INFORMATION

To meet the requirements of its applications, a GIS must offer data structures which make a strict distinction between object information and (carto-)graphic information. The terms Digital Landscape Model DLM and Digital Cartographic Model DCM are increasingly being used here. The former describes the object shape, position, type and characteristics with maximum precision and in a versatile and comprehensive way for all envisaged applications. It is no less essential that the object data permit the program-controlled derivation of cartographic information as a prerequisite for map production. The DCM, in turn, describes a specific map, e.g. the position, shape, size, alignment and colour of the symbol for a church or of the typeface of the map title.

This separation between DLM and DCM can be achieved by different methods. The solution used in PHOCUS is matched to the requirements on hand:

a) If the production of the DCM does not call for operator intervention (because all generalization procedures have already been incorporated during data acquisition), the DCM is produced by program-controlled graphics generation using a graphic code stored in the form of a table. The DCM need not be stored in this case.

b) If generalization procedures are still necessary for DCM production, the relevant data is selected in the DLM data base, generalized under program control and stored in a DCM data base. The operator is now able to revise the stored DCM on the display terminal (e.g. shifting of symbols). The DCM is then available to the user.

In case a), data acquisition is geared to the production of a specific map, i.e. it is **map-dependent**. This method will become increasingly rare in GIS-oriented work and will therefore not be dealt with in further detail here, especially since it has been common practice for years.

However, if the GIS is intended for the production of different types of map, the DLM must be largely **map-independent**. In the following chapter we will look at the repercussions of this requirement on data acquisition.

3. MAP-INDEPENDENT DATA ACQUISITION

Several different methods and means - some competing, some complementary - exist for data collection for a GIS. Competing methods are, for example, map digitization and the stereoplotting of aerial photos, both of which can be performed with PHOCUS.

Map digitization is usually slightly more cost-effective. On the other hand, the third dimension is missing (with the exception of contour lines and height data) and the map, and thus the resulting data, are often obsolete and inhomogeneous.

The **plotting of aerial photos** using analytical plotters therefore offers maximum benefit in data acquisition and is usually indispensable in data revision. Needless to say, the map-independent data acquisition discussed here can be performed more successfully by using aerial photos than maps.

In map-independent data acquisition, the **object generalization** for DLM generation can be performed with less care, due to the possibility of simply collecting more objects, object details etc. than may be necessary. In this case, of course, the subsequent computer-supported generalization for a DCM must be able to compensate for inadequate object generalization (see chapter 4), which means, for example, that houses which are too small and insignificant for representation at the required scale are eliminated.
It is essential that the operator be familiar with the basic principle of this subsequent processing method in order to be able to include appropriate instructions in the data. A relatively small building, for example, may be important for the map if it is in an isolated location and constitutes a prominent point of orientation in the terrain. An instruction should then be given to ensure its retention in the subsequent generalization process - if necessary, in enlarged representation.

In this approach, extremely few **map annotations** are collected in the photogrammetric instrument. Generally, the only annotations still used are descriptions of infrequent attributes, which on the one hand can be interpreted in the aerial photo and on the other hand can best be checked by annotations in the display graphics (e.g. "stadium" or "power station"). Contour annotations are not yet included at this stage either, as their location is very much dependent both on the overall and local map layout.

Graphic line interruption for the insertion of objects can or must also be dispensed with in this object-oriented acquisition process. This means that contour lines, for example, can be measured quite independently of buildings and roads.

The operator's workload on an analytical plotter is substantially reduced if he is able to interpret and measure an aerial photo without having to make allowance for a specific, cartographic end product. The overall time needed until the actual output of the map, however, is barely reduced in map-independent acquisition, as the map-dependent activities are only transferred from the photogrammetric instrument to a different workplace and only part of them can be automated.

Certain limits, however, are set to this approach by the ability of currently available solutions - including PHOCUS - to provide computer-controlled cartographic generalization only for a limited range of scales and specific generalization procedures.

Total independence from map-inherent constraints therefore is not attainable, as will be explained below. (Strictly speaking, the term data acquisition "with reduced map dependence" would be more appropriate).
The above comments should therefore be seen in the context of the following chapter.

4. PRODUCTION OF DIGITAL MAP MODELS

Assuming that we have collected the GIS data more or less independently of a specific map, i.e. very little object generalization has been performed, a range of functions can then be used in PHOCUS, permitting computer-supported, graphic generalization for different Digital Map Models. In the following, we will concentrate on functions which feature a high degree of automation. In addition, a large number of general editing functions can be applied for generalization, such as the interactive shifting or deletion of individual points. These options will not be dealt with in further detail here.

4.1 Definition of the graphic code

On the basis of precise and unambiguous specifications, a graphic code describes the symbols which are used to represent different types of map objects in a specific map (e.g. line width, symbol shape and size). Moreover, it often contains information on the map layout which is not, however, precise and leaves considerable scope for interpretation (e.g. generalization instructions such as "the typical character must be retained").

Virtually any graphic code of topographic maps can be transformed in PHOCUS into a form suitable for automation using special graphic tables and the relevant processing software. Imprecise parts of a graphic code, however, cannot be formulated in these tables, as they are not compatible with the nature of a computer program. If these parts cannot be expressed more precisely, they must be taken into account by the operator during data acquisition or interactive processing.

The PHOCUS user generates a special graphic table for each graphic code and map series. Since the different graphic codes employed by a user normally display a high degree of similarity, these versions are very easy to produce by simple copying of an existing graphic table and appropriate modification of the copy.

Due to the nature of a graphic code, graphic tables do not contain any instrument data. Instead, the special features of the instrument can be included in instrument-specific tables, e.g. number of tools (in tracing tables) or colours (in display terminals), type of tools (ink pen, scriber etc.), stock of symbols which can be generated in the instrument.

This modular structure offers the user a high degree of flexibility. The fast interchangeability of the graphic codes, for example, allows the use of representation techniques on the display terminal which, while providing a slightly simplified version of the final map (e.g. double spacing of hachures), also ensure that the photo interpretation process is monitored. This reduces the amount of graphic data and permits even shorter processing times in interactive graphic editing.

4.2 Generalization of the contour lines

The cartographic generalization of contour lines mainly comprises the following procedures:

1. **Selection** using larger height intervals than in the original map.
2. **Displacement** due to the representation of traffic routes with additional width.
3. **Simplification** using minimum graphic dimensions for the smallest details to be represented.
4. **Emphasizing** of characteristic terrain features.
5. a) **Line interruption** for buildings, roads, water surfaces etc.
   b) **Line interruption** for densely built-up areas.
6. **Annotation** to the extent required but without impairment to the appearance of the map.

Steps 1, 3 and 5a can be automated with PHOCUS. Suitable parameters permit the adaptation of these procedures to the requirements of the scale change involved. Since a data base contains a large variety of objects which are not affected by these generalization procedures, the relevant objects are selected by specification of the object class, object code, attributes, coordinate windows etc.

The remaining steps, except number 2, are unsuitable for full automation as they cannot be formulated with sufficient precision. PHOCUS, however, offers various editing functions which permit the fairly smooth and efficient performance of these procedures in line with the local conditions in the map field. For example, a line intersecting several contour lines can be defined by digitization of two points, and the contour lines can be automatically annotated at the intersection points.

Moreover, a selection can be made for the contour lines to be annotated, e.g. the 10 m lines.

The function available for the interruption of contour lines for buildings etc. (step 5a) is also applicable to those areas which only appear in the final target-scale representation such as the densely built-up areas mentioned under 5 b). All the operator needs to do is enter the edge of such an area, which is rapidly done using the TRANSFER LINE function, and have it integrated into the interruption procedure.

4.3 Generalization of the representation of buildings

The automation of the cartographic generalization of buildings presents considerably greater difficulties than that of contour lines, and has been the subject of extensive research during the last 20 years. Cooperation in this field between the Institute for Cartography of the University of Hanover (IfC) and Carl Zeiss has now resulted in the very first commerical product to solve this problem. The solution is based on programs which were developed at the IfC using a method proposed by Staufenbiel /Staufenbiel 1973/, and which have since undergone intensive tests and enhancements /Hake, Hoffmeister 1978/, /Menke 1983a/, /Meyer 1989/.

These programs, which have been combined under the name of ANGI, enable the following generalization procedures:

1. **Checking and correction of data**

   Recognition and correction of obvious acquisition errors such as the overlapping of two buildings, loops in building contours, incomplete enclosement of areas, etc.

2. **Type grouping of buildings**

   Different types of building (e.g. "residential buildings", "commercial buildings") can be grouped into a new, general category (e.g. "building") in the derived map. The dividing line between adjacent buildings originally of different types can be eliminated.

3. **Elimination of insignificant buildings**

   Buildings whose surface area falls short of a selectable threshold value and which have not been classified as an "important building", are eliminated. Otherwise they are enlarged to a selectable minimum size.

4. **Simplification of building contours**

   Individual lines of the building contour which are shorter than a selectable threshold value are either eliminated or replaced by lines of sufficient length. In this process, the typical shape of the building or its parts is emphasized in accordance with the requirements of the target scale.

5. **Combination of buildings**

   Adjacent buildings spaced by less than a selectable threshold distance are combined. The two buildings, whose typical shapes are retained, are connected if they are of the same approximate size (selectable threshold values). Otherwise, the smaller is attached to the larger building. The resulting dividing line between the two buildings can optionally be eliminated.

After completion of this procedure, the new building contours can and should be simplified once again by procedure 4.

The operation and use of ANGI in PHOCUS requires no specialist knowledge. For the selectable control parameters, recommendations and examples are given which can very easily be applied to all scale changes in the range from 1:500 to 1:25,000.

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4.4 Generalization of traffic route representation

Like buildings, traffic routes should be substantially generalized, starting at map scales of approx. 1:5000 and under all circumstances from 1:10,000 onwards. This applies in particular to town maps where the street symbols must be clearly recognizable and must also leave sufficient space for the street names. Therefore, they are often shown in different colours and widened, even at a scale of 1:10,000.

Due to the paramount importance of this area, the development of a traffic route generalization feature in PHOCUS has now been commenced as a third step after the generalization of contour lines and buildings. We worked again with the IfC, using the methods described in /Menke 1983b/ and /Powitz 1988/ as a basis.
(*Note:* In the following, the term traffic routes mainly refers to roads and streets).

The software modules resulting from this development permit the following generalization procedures on traffic routes:

1. **Type grouping**

   Small-scale derived maps usually include relatively few road types, which means that different or less varied object codes are used here. The object codes of the initial DLM are transformed into the object codes of the relevant DCM using a suitable table. This also permits initial selection of the route types to be omitted in the derived map (e.g. footpaths).

2. **Determination of traffic route axes and network topology**

   To prepare the subsequent steps, the axes and widths of all roads can be determined from the road contours. In addition, the topology - i.e. the nodes and arcs of the complete traffic network - is established in this step. For this purpose, the road axes must usually be extended to intersect each other, resulting in nodes at junctions and crossroads. The arcs describe the connections which exist between these nodes in the network.

3. **Simplification**

   The path of the traffic route axes can be simplified in accordance with the requirements of the target scale.

4. **Widening**

   A new double-line symbol which is symmetrical to the road axis can now be computed on the basis of the graphic code of the target scale. Depending on the map scale, it may be wider than the actual object, and the extra width is determined for the subsequent displacement process.

5. **Correction of road junctions**

   The symbols generated in step 4 still display gaps and overruns at road junctions. Such gaps can be closed and overruns eliminated, both in an automatic process.

6. **Displacement**

   The extra-wide representation of a road necessitates the displacement of adjacent objects, and of houses in particular. In the current version, all buildings which may be affected by the displacement are marked with a special identifier. This permits them to be automatically highlighted on the graphic display terminal, followed by interactive processing. This procedure will be largely automated in the enhanced versions.

Like the previously mentioned ANGI, all modules for traffic route generalization are very easy to handle and have been tailored to the requirements of a production company.

5. OUTLOOK

Map-independent data acquisition and largely computer-supported cartographic generalization methods will be the working modes of the future in practical applications. This provides the user with the following outstanding benefits:

- reduced workload for the operator on the photogrammetric plotter, resulting in **cost and time saving in data acquisition,**
- more flexible use of the data for different map types or map series and therefore **more effective utilization of the data,**
- faster production of maps at different scales and therefore **greater actuality of the map contents.**

The advantages will be further increased as the capabilities of computer-supported cartographic generalization are extended. But even at the present stage, the capabilities offered by PHOCUS are already of great benefit to the user.

REFERENCES

HAKE, G., HOFFMEISTER, E.-D., 1978: **Computergestützte Gebäudegeneralisierung.** Kartographische Nachrichten 1/78, pp. 47 - 55

MENKE, K., 1983a: **Ein Beispiel rechnergestützter Generalisierung für die TK 25.** Nachrichten aus dem Karten- und Vermessungswesen, Series I, Vol. 92, Frankfurt am Main 1983

MENKE, K., 1983b: **Zur rechnergestützten Generalisierung des Verkehrswege- und Gewässernetzes, insbesondere für den Maßstab 1:25000.** Wissenschaftliche Arbeiten der Fachrichtung Vermessungswesen der Universität Hannover, Vol. 119, Hannover 1983

MEYER, U., 1989: **Generalisierung der Siedlungsdarstellung in digitalen Situationsmodellen.** Wissenschaftliche Arbeiten der Universität Hannover, Vol. 159, Hannover 1989

POWITZ,B.M., 1988: **Automationsgestützte Generalisierung von Verkehrswegedarstellungen.** Nachrichten aus dem Karten- und Vermessungswesen, Series I, Vol. 101, Frankfurt a.M. 1988

STAUFENBIEL, W., 1973: **Zur Automation der Generalisierung topographischer Karten mit besonderer Berücksichtigung großmaßstäbiger Gebäudedarstellungen.** Wissenschaftliche Arbeiten der Universität Hannover, Vol. 51, Hannover 1973

ABSTRACT

A geographic information system should permit largely automatic production of maps with a wide variety of content and scales. If this is to be achieved, the systematic separation of object and graphic data is vital, both during data acquisition and in the data structure. In addition, programs for computer-supported cartographic generalization are required. This paper shows that the latest PHOCUS developments already meet these requirements to a high degree.

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PHOCUS FÜR KARTOGRAPHISCHE ANWENDUNGEN

ZUSAMMENFASSUNG

Ein Geographisches Informationssystem sollte die Möglichkeit bieten, Karten verschiedensten Inhalts und Maßstabs auf weitgehend automatische Weise herzustellen. Eine wesentliche Voraussetzung dafür ist die konsequente Trennung von Objekt- und Graphikinformation während der Datenerfassung und in den Datenstrukturen. Weiterhin sind Programme zur rechnergestützten kartographischen Generalisierung erforderlich. Dieser Beitrag zeigt, daß die neuesten Entwicklungen zu PHOCUS diese Anforderungen bereits in erheblichem Maße erfüllen.

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