

COMPUTER - ASSISTED CARTOGRAPHIC GENERALIZATION AND ITS PRACTICAL APPLICATION WITH PHOCUS

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ABSTRACT

Research in computer-assisted cartographic generalization has entered a phase that affords practical implementation. This paper gives a short overview of the ideas and concepts in this field and of their relevance in the age of geographical information systems. The second part of the paper deals with the solution of computer-assisted cartographic generalization as integrated in PHOCUS, the universal photogrammetric and cartographic system from Carl Zeiss. This solution for large- and medium-scale applications enables nearly automatic generalization of buildings and traffic routes. A semi-automatic solution is provided for the displacement problem. Special emphasis is placed on the practicability of the used method also by means of exemplary results. Apart from purely geometric generalization, conceptual generalization, i.e. generalization of the attribute data, is also dealt with. In this context, the relational data structure for attribute data in PHOCUS is described.

KEY WORDS Cartographic, Data Base, GIS/LIS, Mapping, Photogrammetry

1. INTRODUCTION

Computer-assisted cartographic generalization has been a research topic for more than two decades. A large number of publications appeared in the seventies which, due to hardware and software restrictions, were of a rather theoretical nature. With the elimination of these restrictions and the possibility to make practical tests, it became obvious that this complex problem had to be solved in stages.

Late in the eighties, a large number of partial solutions with sometimes noteworthy results existed. The object was and still is to integrate these partial solutions in a generalization package and to progress on the road from research and development to practical application.

Carl Zeiss now introduces the modular CHANGE system, a complex generalization package for practical use. CHANGE has been developed by the Cartographic Institute of the University of Hannover and is fully integrated in PHOCUS, the universal photogrammetric and cartographic system from Carl Zeiss.

2. COMPUTER-ASSISTED CARTOGRAPHIC GENERALIZATION

2.1 Relevance

The use of space-related information is currently subject to fundamental change. Today the classical map is just one of many possible forms of presenting such information. This is why the question arises what relevance a cartographic method like generalization might have. Is it still required in the age of geographical information systems? - Upon closer inspection, the answer quickly becomes obvious: The need for automated generalization methods is considerably increased by these new technologies because:

- Graphical presentation of varied space-related information requires very diverse representations of the basic spatial data (from detailed to very generalized).
- The useful life of the data is much longer than that of the hardware and software. This means that the data base has to be kept as flexible as possible.
- The cost and the time required for scale-dependent data acquisition and editing and for the management of spatial data bases with different scales can be minimized by the use of computer-assisted cartographic generalization.

Furthermore it is rather anachronistic to derive digital successor maps from digital basic maps by means of manual methods, i.e. the higher the degree of digitization in cartography, the more urgent the need for the methods described here.

2.2 Exemplary approaches

The theory of cartographic generalization is characterized by different approaches. Initially the following major procedural steps can be distinguished /1/:

- *Simplification*
- *Enlargement*
- *Displacement as a result of enlargement*
- *Combination*
- *Selection and elimination*
- *Classification and typification*
- *Evaluation and emphasizing*

These may again be broken down into

- *geometrical and*
- *geometrical-conceptual methods,*

with a clear distinction sometimes being impossible.

Practical experience with automatic methods has shown that it makes sense to use different generalization methods for different object types. For example, the methods used for natural objects can, in general, not be used for artificial objects like buildings.

In addition, a distinction has to be made in computer-assisted cartographic generalization according to the used data types. This distinction is used here in the following. Precise information on the methods is given in the literature (e.g.: /2/, /5/). Only a short list of major ideas is given here that is not intended to be complete.

2.2.1 Vector data approach

Advantage: Precise geometric calculations possible.

- Examples:*
- Building generalization through the elimination of small sides
 - Line generalization by matching splines or polynomials, by running averages or by filtering methods,
 - Displacement by linearly decreasing displacement amounts starting from a zone of maximum displacement
 - Center-axis determination of area or double-line traffic arteries.

2.2.2 Raster data approach

Advantage: Elegant handling of area problems

- Examples:*
- Line simplification by filtering and skeletoning methods
 - Object symbolization with pattern recognition methods.

2.2.3 Hybrid approach

Offers the advantages of both data types

- Example:*
- Recognition of object overlaps after enlargement in the raster data format followed by displacement in the vector data format.

2.2.4 Expert systems

Complex interactions between objects particularly during displacement or conceptual generalization can be assigned to the objects as "knowledge" (object-oriented approach).

This allows automating some subproblems of generalization not governed by precise rules by comparison with similar work done in the past. However, this field still is in the early research stage.

3. THE 'CHANGE' GENERALIZATION PACKAGE FOR PHOCUS

Since its introduction in 1987, PHOCUS from Carl Zeiss has become one of the leading photogrammetric-cartographic systems in the world.

The integration of the CHANGE generalization package now offers the PHOCUS user a unique range of applications in computer-assisted cartographic generalization.

3.1 System overview

CHANGE is a modular package of distinct generalization procedures. The distinction is primarily based on the type of objects to be generalized and not on the required procedure steps. The concept is thus open to expansion by additional modules.

The following are currently supported:

- Building generalization
- Traffic route generalization
- Detection of displacement problem areas and support of interactive editing

The standard PHOCUS functions furthermore allow automating a large number of cartographic procedures such as reserving space for texts or labeling contour lines.

Fig. 1 illustrates the integration of CHANGE in PHOCUS.

The PHOCUS data selection interface is used to start generalization by calling the

GEODA (GEneralize Object DATA)

function. The user only has to define the data base containing the input data and the destination data base.

The generalization methods to be used and the associated parameters have to be defined beforehand in a control file. This is dealt with in the following sections.

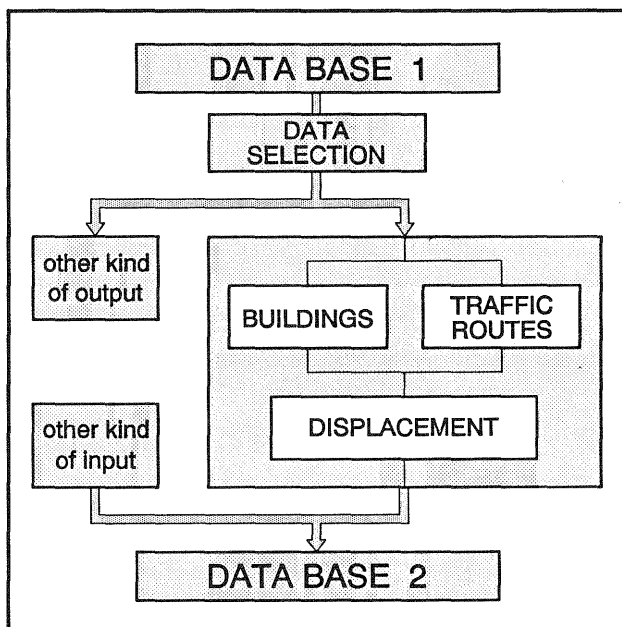


Fig. 1 PHOCUS Generalization Facilities

The user can make use of the full range of selection options provided by PHOCUS for selecting the data from the input data base. This means that virtually random subsets of the input data base may be used for generalization. For example, this allows thematic preselection of the objects to be included in the output representation.

The procedural steps for building and road generalization that are shown as monolithic blocks in Fig. 1 are subdivided into subprocedures that can be selected in the control file. This is also dealt with in the following sections.

3.2 Building generalization

Building generalization involves the following subprocedures /3/:

- Data checking and correction, if required
- Typification
- Elimination of irrelevant buildings
- Simplification of building outlines
- Combination of adjacent buildings
- Simplification of combined building outlines

These subprocedures need not all be used every time. For example, the user can decide only to perform a data check. The elimination, simplification and combination subprocedures are controlled by a series of geometrical and conceptual parameters.

Fig. 2 illustrates the building outline simplification parameters.

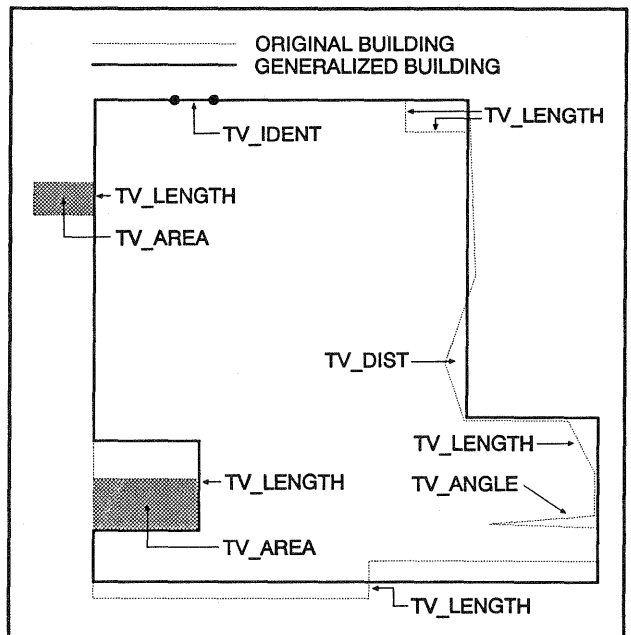


Fig. 2 Simplification of the outline

- Meanings:*
- TV_LENGTH: Minimum length of a building side
 - TV_DIST: Minimum distance of a point from the line through its two adjacent points.
 - TV_IDENT: Minimum spacing of adjacent points
 - TV_ANGLE: Angle limit for eliminating offset points
 - TV_AREA: Minimum area of an object and (here) criterion for eliminating or emphasizing building projections:
 $\text{Area F}(\text{projection}) > a * \text{TV_AREA} \rightarrow \text{Emphasis}$
 $\text{Area F}(\text{projection}) < a * \text{TV_AREA} \rightarrow \text{Elimination}$
 where a is an internal system parameter (e.g. 0.1).
 The area to be included in the computation is shown shaded in Fig. 2

3.3 Generalization of traffic routes

Due to its modular design, the module for generalization of traffic routes covers a wide field of applications. The major submodules are (Fig. 3):

- Data preprocessing
- Center-axis determination
- Creation of a topological network
- Simplification of this network using different methods (spline or polynomial approximation, Douglas-Paucker filtering, highpass filter)
- Derivation of enlarged double-line roads
- Clarification of the interchange areas

The user can combine these submodules in any meaningful way. The following input data types are legal:

- Areas
- Lines
- Outline polygons (left and right road edges geometrically separated but semantically linked in one object).

The same data types can also be put out with any combination of input and output data types being possible. The potential of this module vastly exceeds pure road generalization. This is shown by the following list of possible applications:

- Generalization of double-line traffic routes to enlarged double-line or single-line traffic routes
- Simplification of line data (e.g. contour lines) without the third dimension being lost
- Road axis determination
- Determination of the network topology of an urban road network to answer questions like "Which is the best way from A to B?".

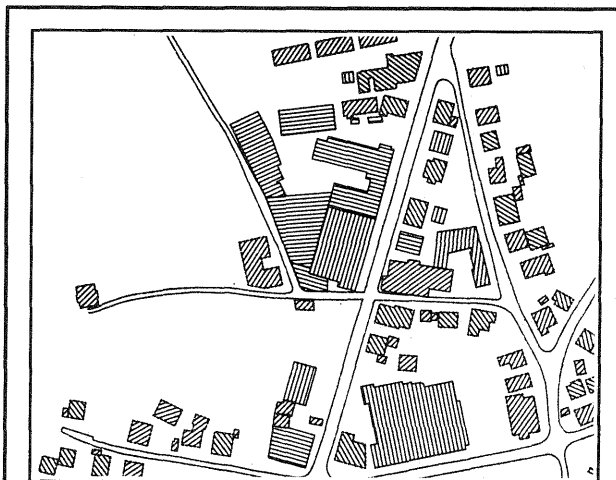


Fig. 5a Base map 1:5000 compiled by photogrammetric data acquisition with P3 Planicomp and PHOCUS

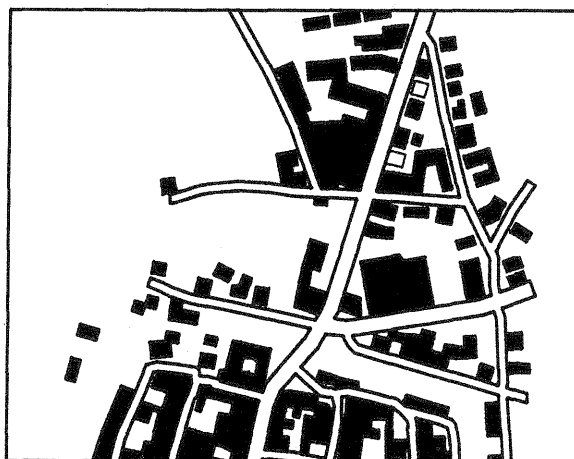


Fig. 5b Result of automatic generalization and interactive revision for a map 1:20 000

Fig. 5 Example 2

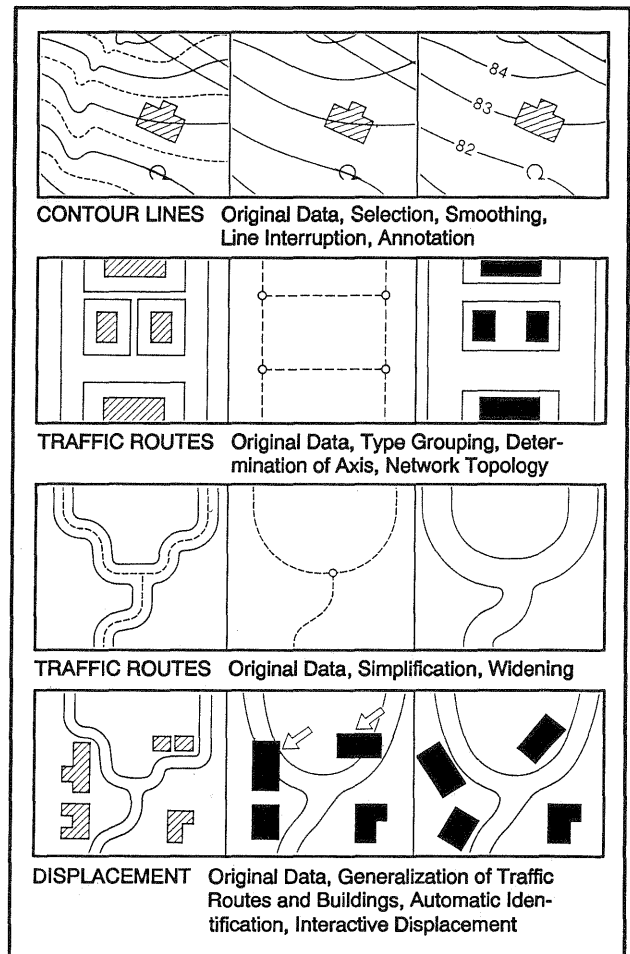


Fig. 3 Generalization of contour lines and traffic routes

3.4 Sample results

Figures 4 and 5 illustrate the potential of the PHOCUS generalization package in a striking way. A complex practical example contains densely built-up urban areas and sparsely built-up marginal areas.

The original data set consists of about 800 objects with about 10.000 coordinates. The derived result data set still contains about 300 objects and about 4.000 coordinates. These numbers only refer to the object types 'building' and 'road'. Generalization of contour lines and water bodies provides about the same results.

4. PROSPECTS

4.1 Future developments

The next large complex that will be dealt with within the scope of CHANGE is displacement automation. This is a complicated procedure that must allow for the interaction between individual objects. Once this problem has been solved, the degree of generalization automation attainable with PHOCUS will progress from the current 80 % to 95 % and more.

The system is open for additional modules that can be integrated with little effort.

4.2 Conceptual generalization

The major currently available concept generalization options are:

- Suppression of the combination of objects belonging to different classes resp. object and object item types
- Suppression of the elimination of important objects which would have to be eliminated by geometrical reasons
- Use of the attributes of the largest object for the combination

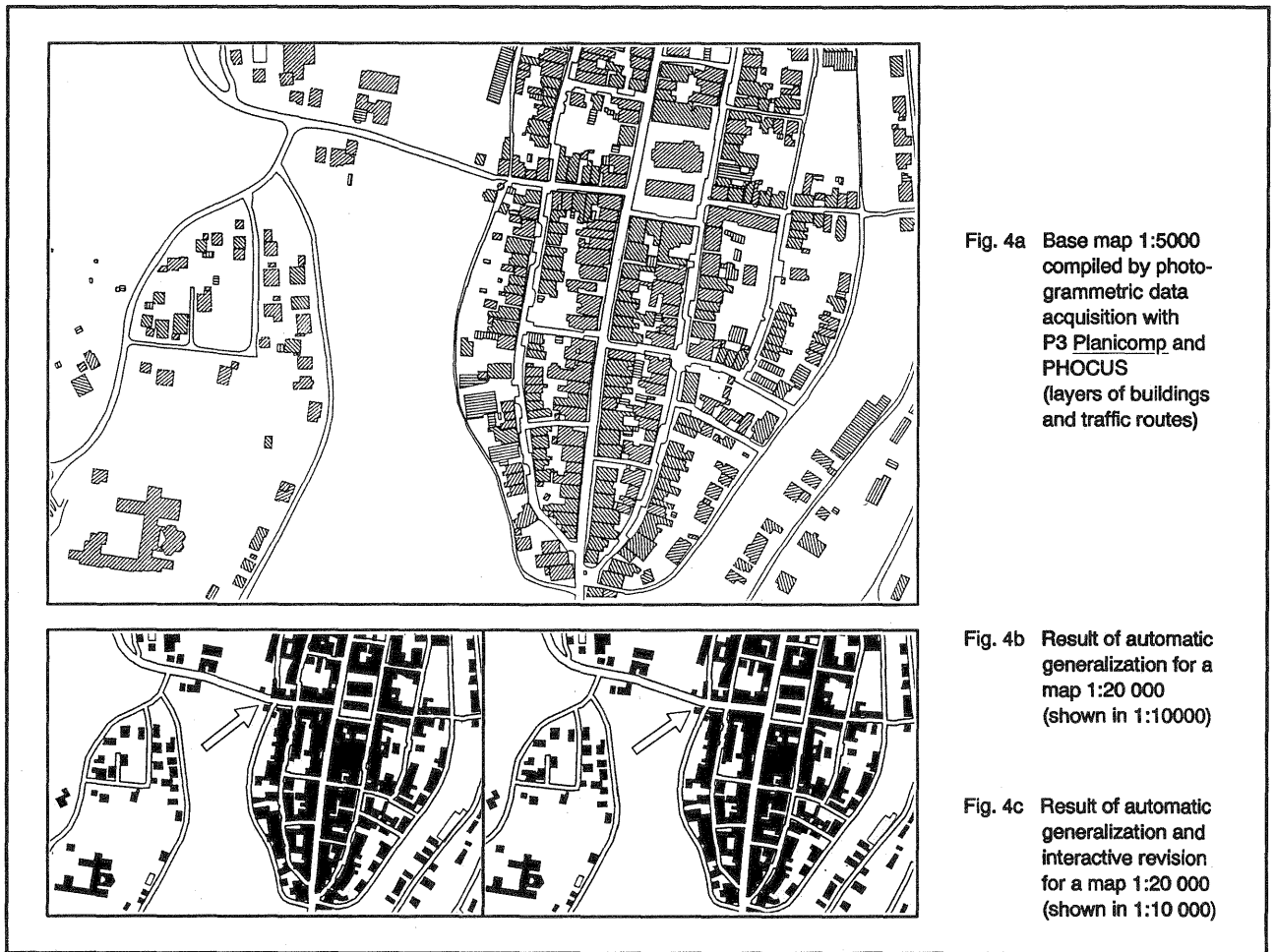


Fig. 4a Base map 1:5000 compiled by photogrammetric data acquisition with P3 Planicomp and PHOCUS (layers of buildings and traffic routes)

Fig. 4b Result of automatic generalization for a map 1:20 000 (shown in 1:10000)

Fig. 4c Result of automatic generalization and interactive revision for a map 1:20 000 (shown in 1:10 000)

Fig. 4 Example 1

Further development in this field will also allow for the extended attribute structure in PHOCUS /4/.

In addition to the standard attributes, the user can combine arbitrary attribute structures with the PHOCUS object types in a data base (ORACLE). For example, all objects in the building class can be assigned the attributes "owner", "construction date" etc.

The manipulation of these attributes during generalization is relevant in particular if the result is to be used as a digital model for small-scale applications e.g. in a GIS. The attribute data then has to be processed according to user-defined rules.

4.3 Conclusions

The increasing volume of digital space-related data will cause computer-assisted methods of cartographic generalization to be accepted and distributed ever more widely.

These methods offer the following major advantages:

- Time and cost savings during data acquisition
- Increased usefulness of the data
- Improved map topicality

Carl Zeiss has taken up this challenge early on and PHOCUS today already enables large-scale automation of generalization procedures.

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