Separate print taken from:
Nachrichten aus dem Karten- und Vermessungswesen, Reihe II: Übersetzungen — Heft Nr. 33
Paper presented to the Eighth International Cartographic Conference
International Cartographic Association (ICA), Moscow, USSR, 1976
Printed and published by Institut für Angewandte Geodäsie, Frankurt a. M. 1976
DK 528.914(084.3-13/-14):65.011.56

Fully Automated and Semi-Automated Interactive Generalization, Symbolization and Light Drawing of a Small Scale Topographic Map

(mit 8 figures and 1 annex)

By Fred Christ, Frankfurt a. M.

SUMMARY: Author describes the test of generalizing the data of four topographic maps 1 : 50 000 for one quarter section of a general topographic map 1 : 200 000.

Procedures of fully automated selection and simplification of point- and line features, of fully automated derivation of compact settlement areas and of semi-automated interactive displacing and selection of features are explained.

Some of the generalized data 1 : 200 000 are graphically represented.

RÉSUMÉ: Auteur décrit une expérience destinée à généraliser les données de quatre cartes topographiques au 1/50 000 pour obtenir un quart de feuille d'une carte générale topographique au 1/200 000.

Il explique le procédé de la sélection automatique et de la simplification d'objets en points ou en lignes, la dérivation automatique d'habitats concentrés ainsi que le décalage planimétrique et la sélection interactifs des objets, exécutés par voie semi-automatique.

Une partie des données généralisées au 1/200 000 est représentée graphiquement.

ZUSAMMENFASSUNG: Der vorliegende Bericht beschreibt den Versuch zur Generalisierung der Daten von vier topographischen Karten 1 : 50 000 für ein Viertelblatt einer topographischen Übersichtskarte 1 : 200 000.

Der Ablauf der automatischen Auswahl und Vereinfachung von Punkt- und Linienobjekten, die automatische Ableitung von geschlossen bebauten Siedlungsflächen und die halbautomatische interaktive Verdrängung und Auswahl von Objekten werden erläutert.

Ein Auszug aus den generalisierten Daten 1 : 200 000 wird graphisch dargestellt.

1. General

In continuation of the experimental automatic generalization and rationalization of map information for a small scale topographic map (see *Gottschalk* [5] and *Christ* [4]), now four neighbouring map sheets 1 : 50 000 have been digitized (see *Uhrig* [8]), edited and rim adapted (see *Johannsen* [7]), generalized and light-drawn to produce one quarter of a map 1 : 200 000.

The goal of this research project is

- the improvement of the digitizing procedures,
- the completion of the fully automated pregeneralization of line features and settlements,

— the application of newly developed semi-automated interactive editing-, rim adaption- and generalizing procedures,

— the gathering of knowledge concerning production times, manpower, and unexpected difficulties resulting from the handling of mass data.

Systems used for the single tasks are

— off-line digitizer Aristo Aristogrid for digitizing,

— large-size computer AEG/Telefunken TR 440 for pregeneralization,

— interactive digitizer Aristo ID 101 for editing and rim adaption,

— interactive cartographic system Contraves Cora 3 for editing, interactive generalization, and light drawing.

The whole project will be finished at the end of 1976.

An intermediate graphical output of some of the processed topographic features is shown on annex 1.

2. Fully automated and semi-automated interactive generalization

2.1. *Approach to a provisional solution*

The procedure of generalizing in derivating a small scale topographic map 1 : 200 000 from a large scale topographic map 1 : 50 000 may be analysed as a function of six primary operations:

— Selection,

— simplification (reduction of sinuosity),

— variation of quantity (size and line width),

— variation of quality (shape, colour),

— displacement,

— merging

of topographic features.

Each operation in itself may be seen as function of quantitative plus qualitative considerations, exclusively qualitative or exclusively quantitative considerations.

So the procedure of generalization forms a complex network of operations which influence themselves mutually (see *Christ* [1], *Christ, Schmidt, Uhrig* [2]).

Associative computer systems, so-called parallel processors, handling map images as raster data would be the most suitable instruments to solve this network task.

As those computers are still extremely expensive, cartography in the near future will probably use today's sequentially working computer systems.

Also the data of the topographic features represented on maps will be produced and processed in sequential digital form, e. g. a coordinate string describing the course of a road, as long as raster scanner digitizing and raster plotter drawing are under research.

For this reason, the following approach to a provisional solution of generalization is being tried at the Institut für Angewandte Geodäsie:

using a large size computer —

a) fully automated selection and simplification of topographic features for the 1 : 200 000 scale map considering quantitative aspects,

using a medium size cartographic automation system —

b) fully automated variation of quantity and quality of the features considering quantitative aspects,

c) semi-automated interactive selection of features considering qualitative plus quantitative aspects,

d) semi-automated interactive displacement of features considering exclusively quantitative aspects,

e) semi-automated interactive merging of features considering qualitative plus quantitative aspects (not yet described in this paper).

Operations (a) influence operations (c) through (e).

Operations (b) influence operations (c) through (e).

Operations (c), (d), and (e) influence themselves mutually.

2.2. *Fully automated pregeneralization*

2.2.1. Input data

Data of the four neighbouring topographic maps 1 : 50 000

L 5914 Wiesbaden
L 5916 Frankfurt a. M.-West
L 5714 Limburg an der Lahn
L 5716 Bad Homburg v. d. Höhe

have been produced by means of an Aristogrid digitizer and have been recorded on magnetic tapes in an internal data format (see *Uhrig* [8]). These data were read into a large size computer TR 440. The data format was converted into a format readable by the later on used generalization programs and intermediately stored on magnetic tapes containing the complete data set for borders, railways, roads, settlements, water lines, contour lines, woods, railway stations, tunnels, bridges, elevation points, trigonometric points, towers, castles, monuments, mines, etc. in several data files.

The data files on the intermediate storage tapes were logically grouped corresponding to the four basic maps 1 : 50 000 and corresponding to the headers (feature codes) of the topographic features.

2.2.2. Selection and pregeneralization of the line features

Line features, also including contours of areas, are a geometrical contiguous sequence of line elements showing the same header.

Line elements are a logical contiguous sequence of points, becoming connected by the same kind of interpolation when the line element is drawn by an automatic drafting machine.

If the sequence of points is connected linearly, the line element is a polygon, if the connection is an interpolation of higher degree, the line element is a curve (see *Gottschalk* [6]).

From the intermediate storage tapes sequentially one map 1 : 50 000 following the other and one feature group e. g. roads, followed by the next one e. g. water lines, were read by the generalization program for the selection and smoothing of cartographic lines (see *Gottschalk* [6]) into the TR 440 computer.

Hereby features not at all represented in the target scale 1 : 200 000 were omitted by header selection e. g. lower class tracks, small ditches, contour lines of a contour interval other than 50 meters, county borders, power lines, etc.

The line features selected for representation at 1 : 200 000 scale then became smoothed by the generalization program using a gliding arithmetic mean.

The degree of smoothing is defined by two input parameters which must be chosen according to the sinuosity of the line features and their point distance at the 1 : 50 000 basic scale, and the wanted sinuosity at the target scale 1 : 200 000.

The first parameter K determines that every K^{th} point of a curve is to be processed by the gliding arithmetic mean.

The second parameter KJ determines the amount of points before and behind the central point of the gliding arithmetic mean, which is to be included into the calculation For this test K = 8 and KJ = 5 were chosen for most of the line features.

Polygon elements of the line features are tested if the length of a polygon side is greater than 2 centimeters. If it is greater, it is left ungeneralized. The starting- and end points of these ungeneralized polygon sides are kept as salient points for the target scale. If the polygon side is equal or smaller than 2 centimeters, auxiliary points are interpolated between the starting- and end points of the polygon side and the polygon is treated like a curve and included into the smoothing.

Generally, the starting- and end points of the line features are kept as salient points for the target scale.

2.2.3. Selection of point features

Simultaneously with the input and selection of the line features of the 4 basic maps 1 : 50 000, the point features e. g. trigonometric points, towers, etc. were input into the TR 440 computer and selected by headers for the representation on the 1 : 200 000 scale map.

2.2.4. Generalization of settlements

The input data for the generalization of the settlements were digitized and stored on the above mentioned intermediate storage tapes in two forms:

a) as line features for the contours of the center blocks of the cities and the contours of large industrial buildings,

b) as point features for all the single houses forming the compact settlement areas and for all the single houses scattered in the open landscape.

The generalization of the contours of the city centers and of the industrial buildings was executed by the same program as used for the generalization of roads, water lines, borders, etc.

For the generalization of the compact settlement areas, the point features "houses" were read into TR 440 by a generalization program for the calculation of areas on the base of point data by means of binary image processing (see *Gottschalk* [6]).

The program determines the boundaries between compact settlement areas and single houses located outside these areas and gives the value 1 = filled to all raster units within these boundaries.

The shape of the compact settlement areas is defined by two input parameters which must be chosen according to the minimum dimension of settlement parts on the target scale 1 : 200 000 and to the significative value of the compact settlement areas.

The first parameter D determines the dimension of the raster units. For this test, a dimension of 50 × 50 meters in nature was chosen.

The second parameter E determines whether the central unit of a nine units square raster is set to 1. For this test, E was chosen as 5. That means when 5 of the 9 raster units are filled, the central unit is set to one. This process is executed iteratively.

Decreasing or increasing the parameter E lets the program enhance or underdemension the compact settlement areas.

The single houses located outside the compact settlement areas were left unchanged by this program.

2.2.5. Output data

The output data of the generalization of cartographic line features were:

- selected and simplified line features and
- selected point features on magnetic tapes,
- check plots of the generalized data by a Benson plotter on-line to the TR 440 computer.

The output data of the generalization of the settlements were:

- point features (raster units with the value 1) for all raster units within the compact settlement areas excluding the center blocks of the cities and industrial buildings on magnetic tapes,

- point features (raster units with the value 1) for all single houses outside of the compact settlements on magnetic tapes,
- check plots of the generalized settlement data by a Benson plotter on-line to the TR 440 computer.

2.3. *Semi-automated interactive generalization*

2.3.1. Input data

The pregeneralized data of the four 1 : 50 000 scale basic maps, which had been output on mangnetic tapes by the two generalization programs on the TR 440 computer were loaded into a cartographic data base of a CORA 3 cartographic automation system (see *Christ* [3]). Five magnetic disk cartridges of the PDP 11/45 computer of the cartographic automation system were used for the storage of the data. The data base was defined in Gauß-Krüger coordinates for one quarter section of the sheet CC 6310 Frankfurt a. M.-West of the general topographic map 1 : 200 000.

The generalized data stored in the data base was then displayed on the Tektronix display of the system in the symbolization for a rationalized map 1 : 200 000 (see *Christ* [4], [3]).

Errors resulting from the original digitizing and from data processing on the large size TR 440 computer were now edited interactively by means of the on-line digitizer and display of the cartographic automation system CORA 3 (see *Johannsen* [7]).

Gaps for overlappings of the generalized features at the rims of the four basic maps, now joined to one section of a 1 : 200 000 sheet, were edited on an interactive digitizer Aristo ID 101 by means of a special rim adaption function (see *Johannsen* [7]). For this operation, the generalized data were transferred via magnetic tapes from the data base of the CORA 3 system to the ID 101 system data base and return.

2.3.2. Semi-automatic interactive displacement of features considering quantitative aspects

Already before editing and interactively generalizing the cartographic automation system, CORA 3 executes fully automatically the variation of quantity and quality of features by looking up symbol tables which are containing line-width, size, and shape definitions of all symbols of the target scale 1 : 200 000. The map image drawn on the display shows the 1 : 200 000 scale symbolization.

Because of the reduction of scale 1 : 50 000 to 1 : 200 000, the space between the symbolized features in the displayed map 1 : 200 000 is vanishing or even the symbols are overlapping, e. g. roads are lying on water lines or houses are lying on roads instead of beside the roads.

Like the cartographer manually draws the signatures slightly displaced, preserving natural proportions, the cartographer now displaces the symbolized features by means of the digitizer and display of the CORA 3 automation system using the editing functions REPLACE SINGLE POINT (RPS) and TRICKMOVE (MIP).

By use of the RPS function, point features are displaced into any wanted direction and distance from their previous position.

By use of the MIP function, line features like roads, water lines, contour lines are moved away from other features and are slightly deformed. But the starting- and end points of a moved section of a line feature are held at their original positions. The amount of displacement is continuously increasing from these two connection points to the point, where maximum displacement is reached. The cartographer determines the displacement by graphical input of displacement vectors by the cursor of the digitizer or cursor of the display. The displaced line features or point features are at once drawn on the display and the cartographer can check whether the result is acceptable. If it is, he accepts the result, otherwise he repeats the function as many times as is necessary.

Figure 1 through 3 are showing the displacement of a single house out of a road.

Figure 4 through 6 are showing the displacement of a road out of a creek.

The operations the cartographer has to fulfill are:

— for displacing point features

a) he enters the editing function IDENTIFY OBJECT (IDO) by the menu or the keyboard of the digitizer,

b) he moves the cursor of the digitizer or the display onto the point feature he wants to displace and digitizes this position,

c) if he has hit the feature, the display of the digitizer keyboard is prompting that a feature has been identified in the data base and shows the header of this feature; on the graphic display the feature is marked by a small triangle,

d) he enters the editing function REPLACE SINGLE POINT (RPS) by menu or keyboard,

e) he moves the cursor of the display or the cursor of the digitizer to the position where he wants the point feature to be displaced and digitizes this position,

f) on the display, the point feature is immediately drawn at the new position; because the graphic display is a storage screen, the point feature at the previous position is still shown as long as the map image on the display is totally redrawn.

— for displacing line features

a) he enters the editing function IDENTIFY SECTION (IDS) by menu or keyboard,

b) he moves the cursor of the digitizer or of the display to the starting- and end points of the section of a line feature which he wants to displace and digitizes these two points,

c) on the display of the digitizer keyboard the message is prompted that the edge has been found in the data base and the section is marked on the graphic display,

d) he enters the editing function TRICKMOVE (MIP) by menu or keyboard,

e) he digitizes the displacement vectors by means of the digitizer cursor or display cursor,

f) on the graphic display the newly positioned line feature is immediately drawn,

g) if the displacement is suitable, he enters the editing function ACCEPT MOVED PART (AMP), otherwise he repeats (MIP).

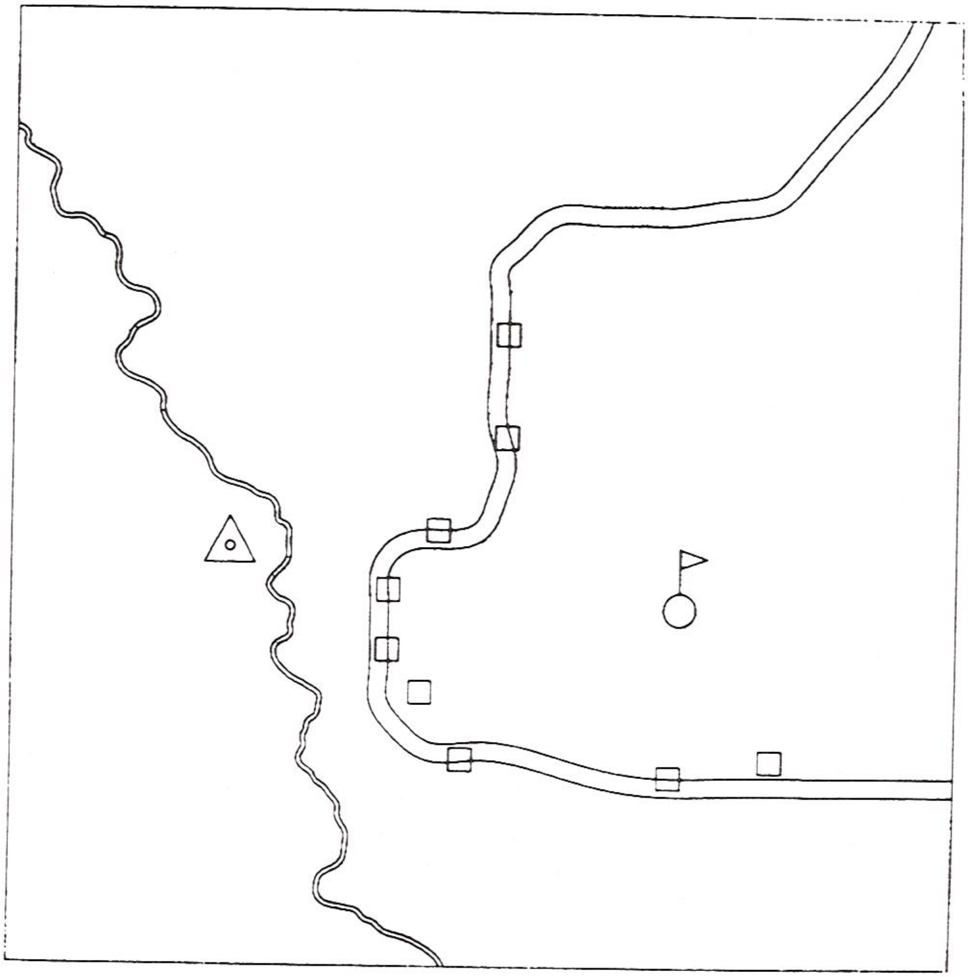


Figure 1

Single houses lying on a road because of scale reduction 1 : 50 000 to 1 : 200 000 and because of 1 : 200 000 symbolization (hardcopy of the display image)

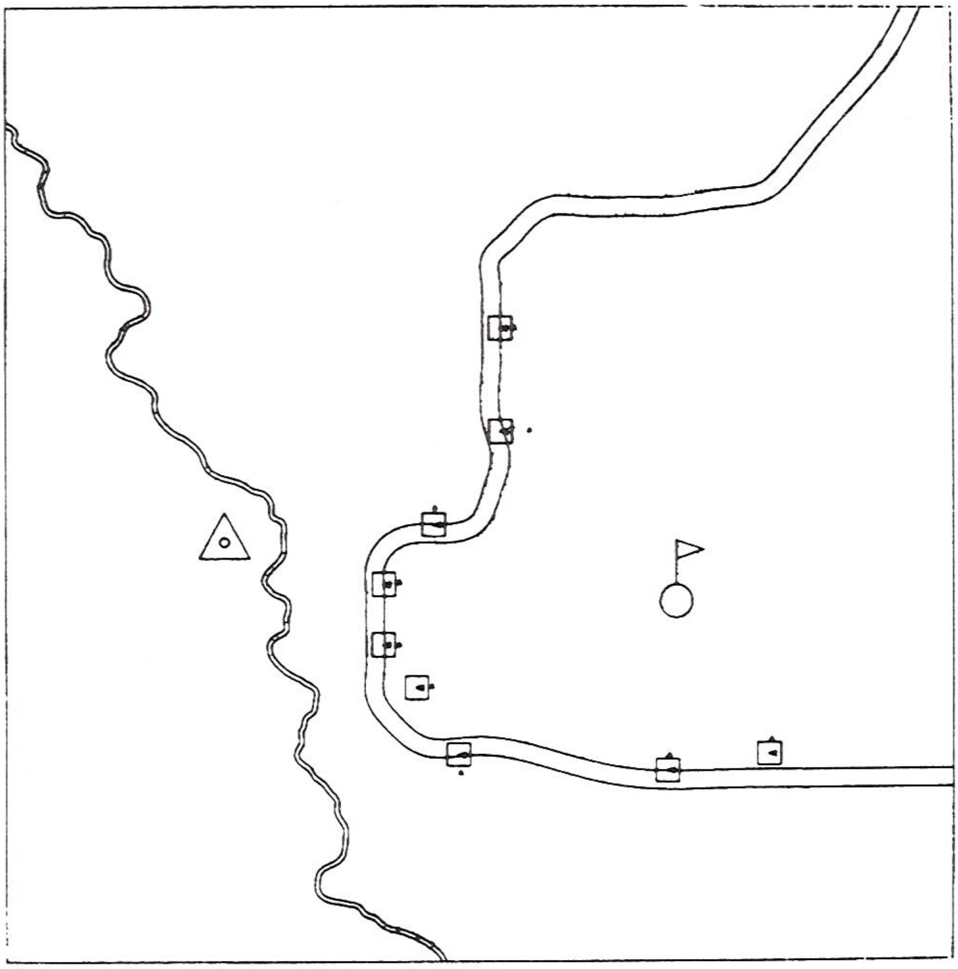


Figure 2

Semi-automated interactive displacement of single houses (hardcopy of the display image)

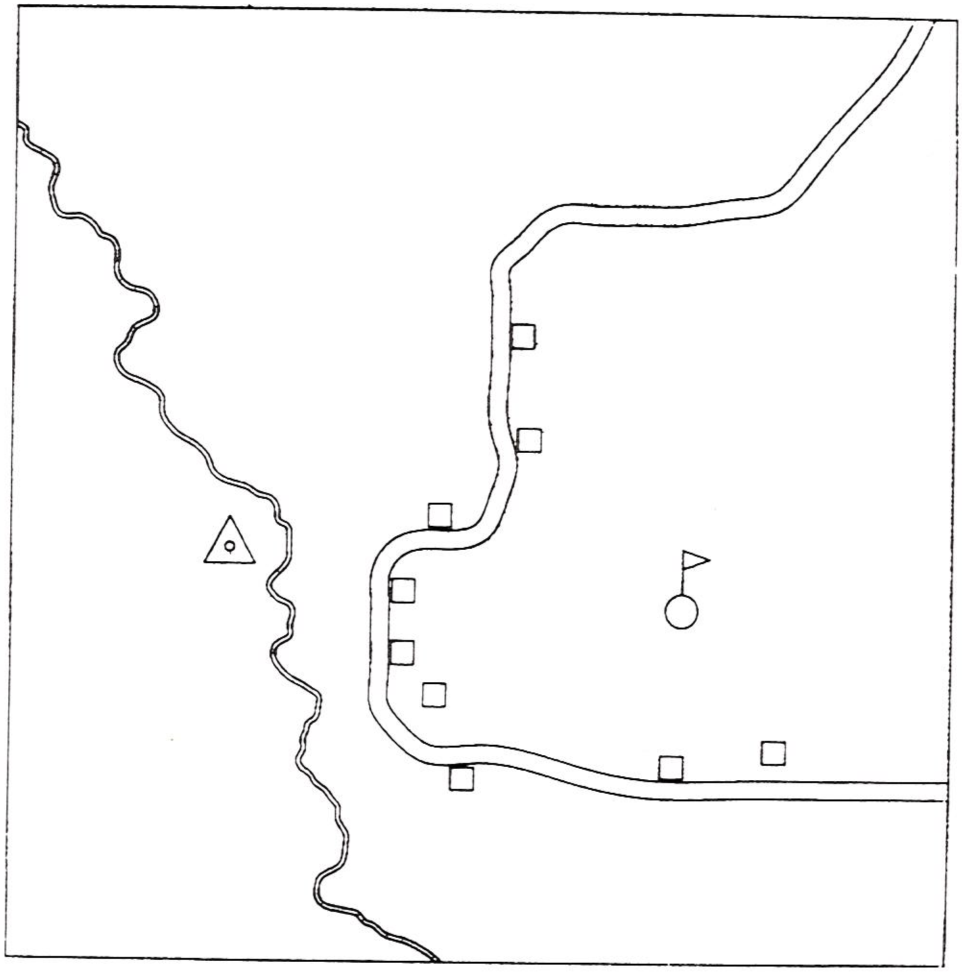


Figure 3
Result (hardcopy of the display image)

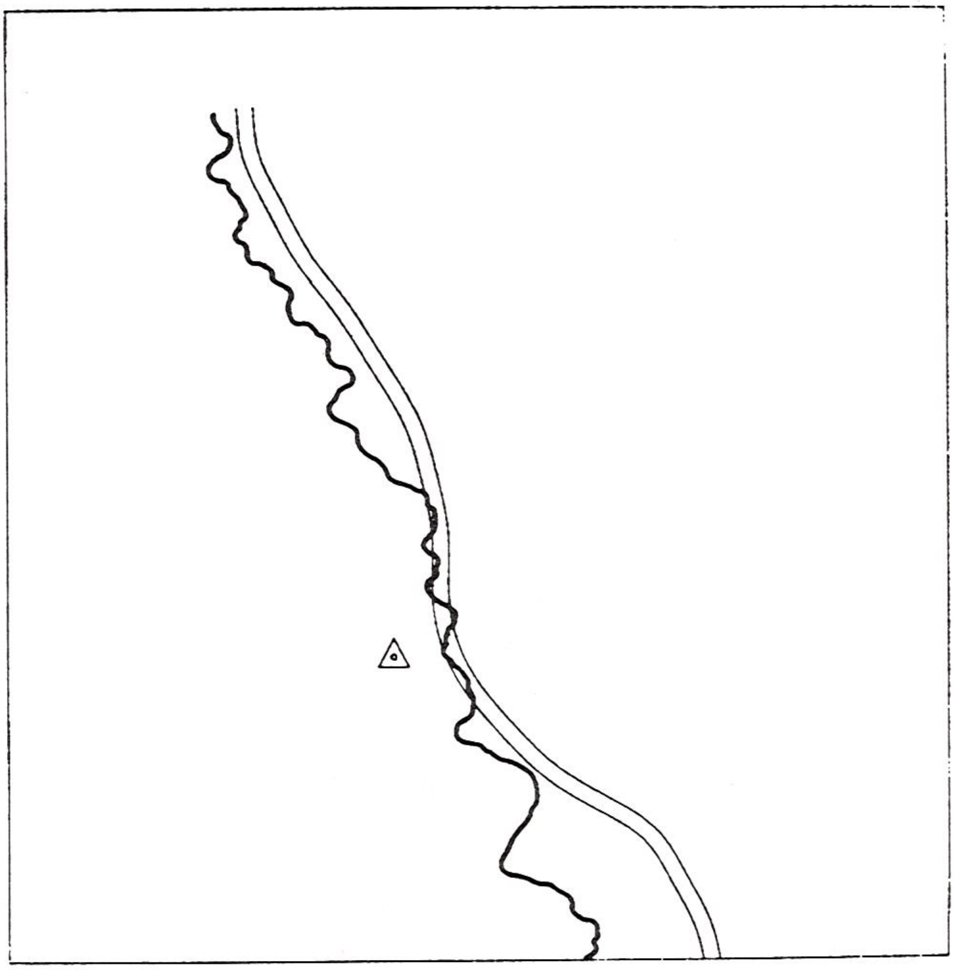


Figure 4

Overlapping of a creek and a road because of scale reduction 1 : 50 000 to 1 : 200 000 and because of 1 : 200 000 symbolization (hardcopy of the display image)

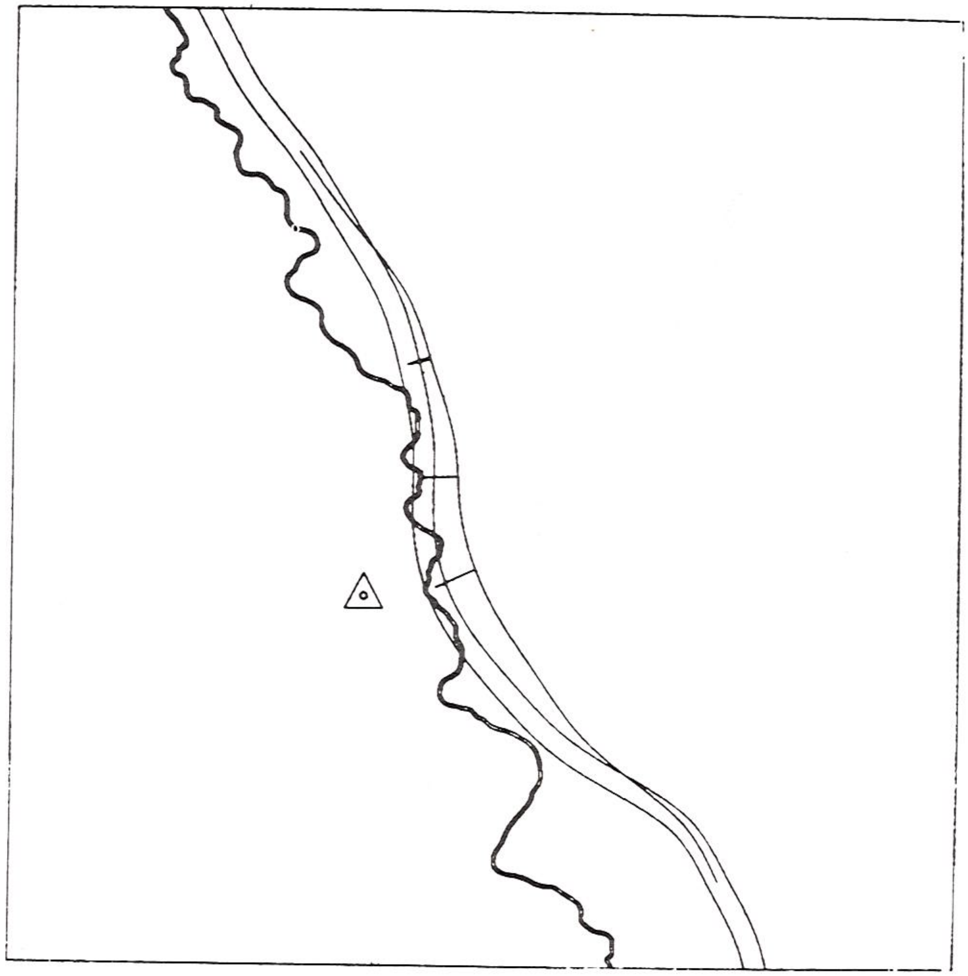


Figure 5

Semi-automated interactive displacement of a road (hardcopy of the display image)

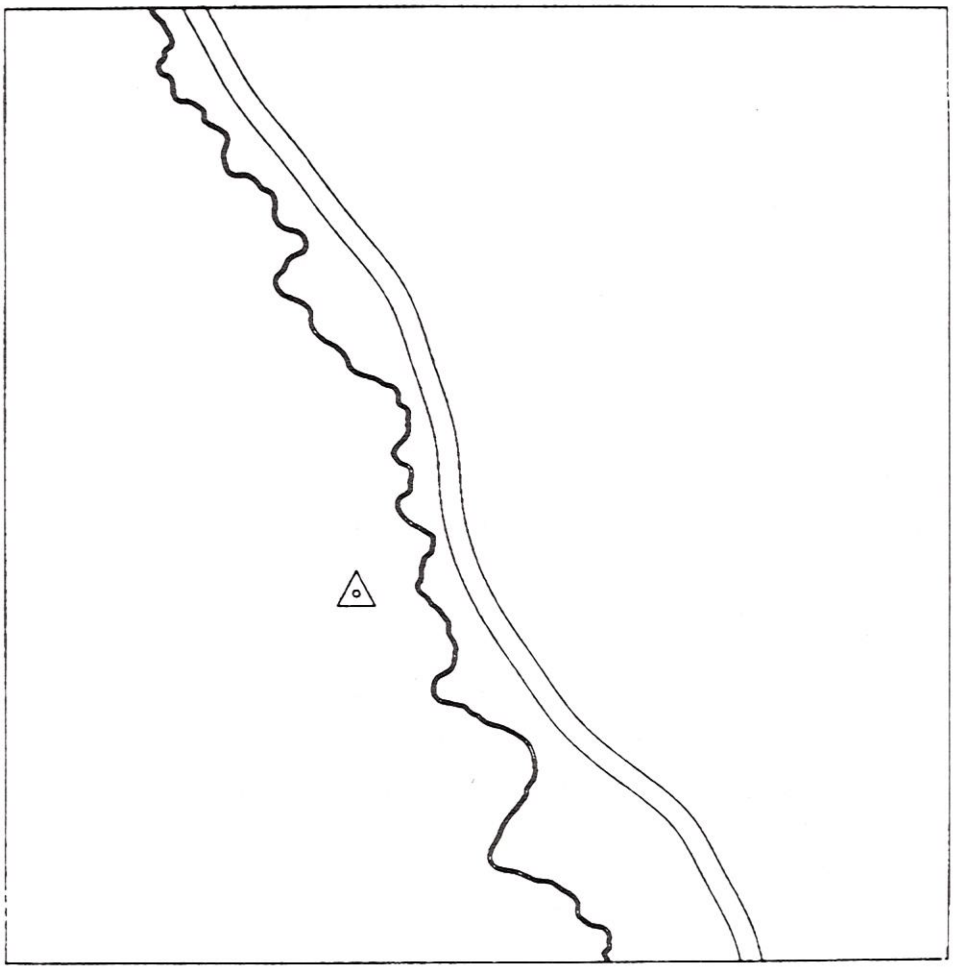


Figure 6
Result (hardcopy of the display image)

2.3.3. Semi-automated interactive selection of features considering qualitative and quantitative aspects

By means of the digitizer and display of the cartographic automation system CORA 3, some features were deleted out of the data base 1 : 200 000. These features were belonging to feature categories which were selected by the two generalizing programs on the TR 440 computer for later on interactive selection.

In these categories, features are free for choice according to their significative value.

E. g. all radio towers were selected by header, but by interactive selection the amount of radio towers in the 1 : 200 000 data base was reduced. Only those radio towers remained, which were positioned on hills or were representing the center of a group of narrow neighbouring towers of a big radio station.

Only those single houses remained in the data base, which were positioned at road crossings or other salient points of the landscape or which were representing a typical structure of the open landscape settlement.

Only those rails of large railway stations remained in the data base, which were sufficiently well representing the structure.

Only those small creeks remained in the data base which represented the structure of the spring area of the main creek or river.

Only those lower class all weather roads remained in the data base, which represented the connection of two salient points like settlements.

Figures 7 and 8 are showing the selection of small creeks.

The operations the cartographer has to fulfill for the selection of features are:

a) he enters the editing function SELECTION (SEL) by the menu or by keyboard of the digitizer,

b) he enters the selection option POINT (PNT) by menu or keyboard,

c) he moves the cursor of the digitizer or the display to the feature he wants to delete out of the data base and digitizes one point on a line feature or the center point of a point feature,

d) the display at the digitizer keyboard is prompting the message that the feature is selected,

e) he once more enters PNT and digitizes an identification point on the next feature he wants to delete,

f) when he has selected all features, he enters the selection option DELETE (DEL) by menu or keyboard and all selected features are deleted out of the data base.

2.3.4. Resulting data

The data resulting from the semi-automated interactive generalization has been stored in the data base 1 : 200 000 of the cartographic automation system CORA 3. A safety backup was output on magnetic tape.

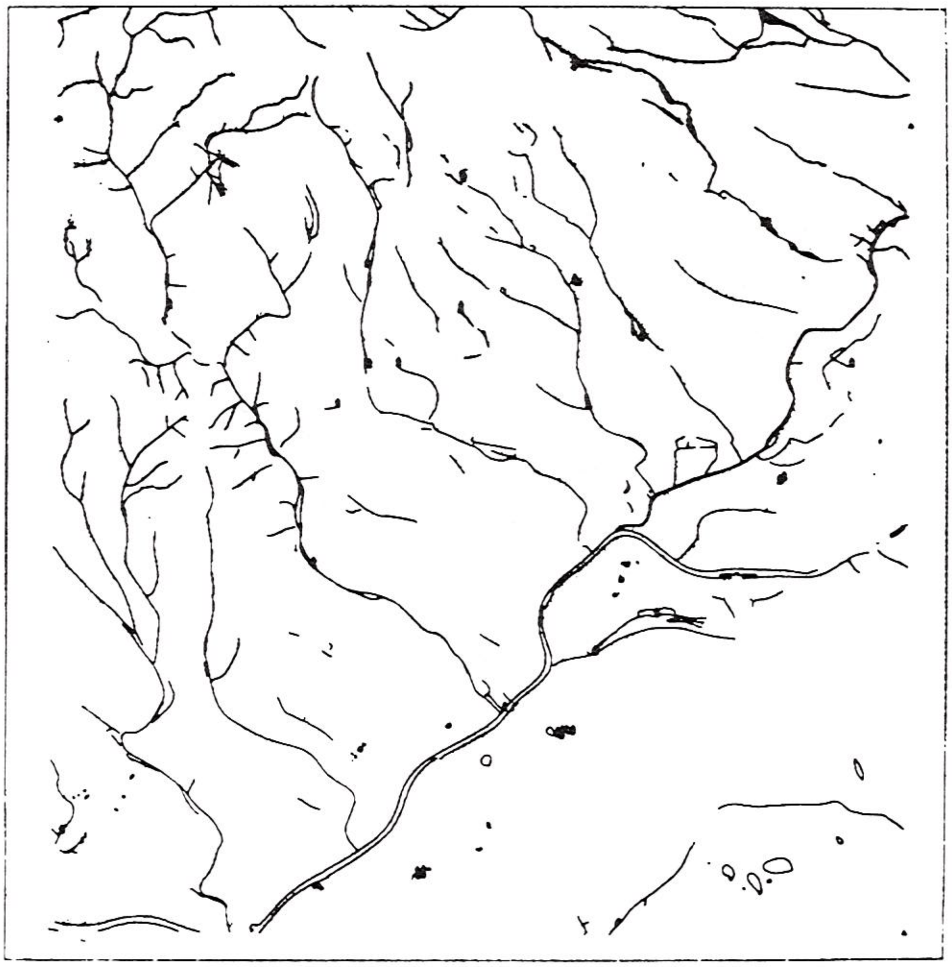


Figure 7

Water lines fully automatically simplified for the 1 : 200 000 scale before semi-automated interactive selection of smaller creeks (hardcopy of the display image)

Figure 8

Result after semi-automated interactive selection of smaller creeks (hardcopy of the display image)

3. Symbolization and light drawing

3.1. Input data

The data of the generalized map section 1 : 200 000 which had been stored in the data base then were selected separately, feature group after feature group e. g. all road features, all contour lines, etc. and output on magnetic tapes as final data files for the light drawing (see *Christ* [3]).

After entering the scale and map type and the headers, the cartographic automation system adds all control statements to these drawing data which the precision drawing machine of the automation system CORA 3 needs for the symbolized light drawing of the 1 : 200 000 map section.

3.2. Output data

Several light drawing films corresponding to the different feature groups were produced by means of the precision drawing machine and its light spot projector.

The fillings of the block center of the cities were added manually on the film containing the generalized contours of the block centers.

Also the crossings of single lines with the dual line motorway was retouched manually.

The films were then printed without further retouching.

4. Consumption of system times

The following times were needed:

- for generalization on the TR 440 computer 5.0 hours,
- for interactive generalization on the CORA 3 System 40 hours,
- for automated drawing 6 hours (compact settlement areas excluded).

5. Conclusion

The test described in this paper will be continued. New ideas have arisen during its procedure. Especially the waste of time, caused by transporting the data from the cartographic automation system to the large size computer and vice versa, and the necessity for data format conversions require new organization forms.

The system times for fully automated and semi-automated generalization are hardly to be decreased at the moment.

The operation of the programs and system functions is still very sophisticated. Here great effort must be invested to simplify the cartographic data processing before introducing computer assisted generalization into production.

The test and its intermediate graphical output presented in this paper are results obtained by the cartographic research group of the IfAG. The colleagues Dr. *W. Weber* and *M. Giebels* completed and extended the generalization programs of Dr. *H.-J. Gottschalk* and executed generalization of the data on the TR 440 computer. *I. Wilski* was responsible for the functioning of the cartographic automation system and for prior tests of the editing functions used. *G. Schleiter* and *E. Schmidt* were executing the interactive generalizing.

Literature

[1] *Christ, F.:* Untersuchung zur Automation der kartographischen Bearbeitung von Landkarten. — Nachrichten aus dem Karten- und Vermessungswesen, Series I, No. 41, Frankfurt a. M. 1969, p. 1—114.

[2] *Christ, F.; Uhrig, H.; Schmidt, E.:* Untersuchung der Generalisierung der Topographischen Übersichtskarte 1 : 200 000 auf mögliche Gesetzmäßigkeiten. — Nachrichten aus dem Karten- und Vermessungswesen, Series I, No. 51, Frankfurt a. M. 1972, p. 15—104.

[3] *Christ, F.:* Automatically Symbolized Output of Map Data Compiled and Selected from a Data Base. — Nachrichten aus dem Karten- und Vermessungswesen, Series II, No. 32, Frankfurt a. M. 1975, p. 5—16.

[4] *Christ, F.:* Rationalization of Map Information on a Topographic Map in Relation to Automatic Production Procedures. — Paper ICA, VIIth Technical Conference, Madrid 1974.

[5] *Gottschalk, H.-J.:* Automatic Generalization of Settlements, Traffic Lines, Contour Lines, Drainage, and Vegetation Boundaries for a Small-Scale Topographic Map. — Paper ICA, VIIth Technical Conference, Madrid 1974.

[6] *Gottschalk, H.-J.:* I. Ein Rechnerprogramm zur Auswahl und Glättung von kartographischen Linien. II. Ein Rechnerprogramm zur Berechnung von Flächen aus flächenartig strukturierten Punktmengen mit Hilfe der Verarbeitung von Binärbildern. — Deutsche Geodätische Kommission, Series B, No. 205, Frankfurt a. M. 1974, p. 1—45.

[7] *Johannsen, Th.:* Automated Procedures with Interactive Editing, Rim-Adaptation, Junction-Purging, and Lettering for a Small Scale Topographic Map. — Nachrichten aus dem Karten- und Vermessungswesen, Series II, No. 33, Frankfurt a. M. 1976.

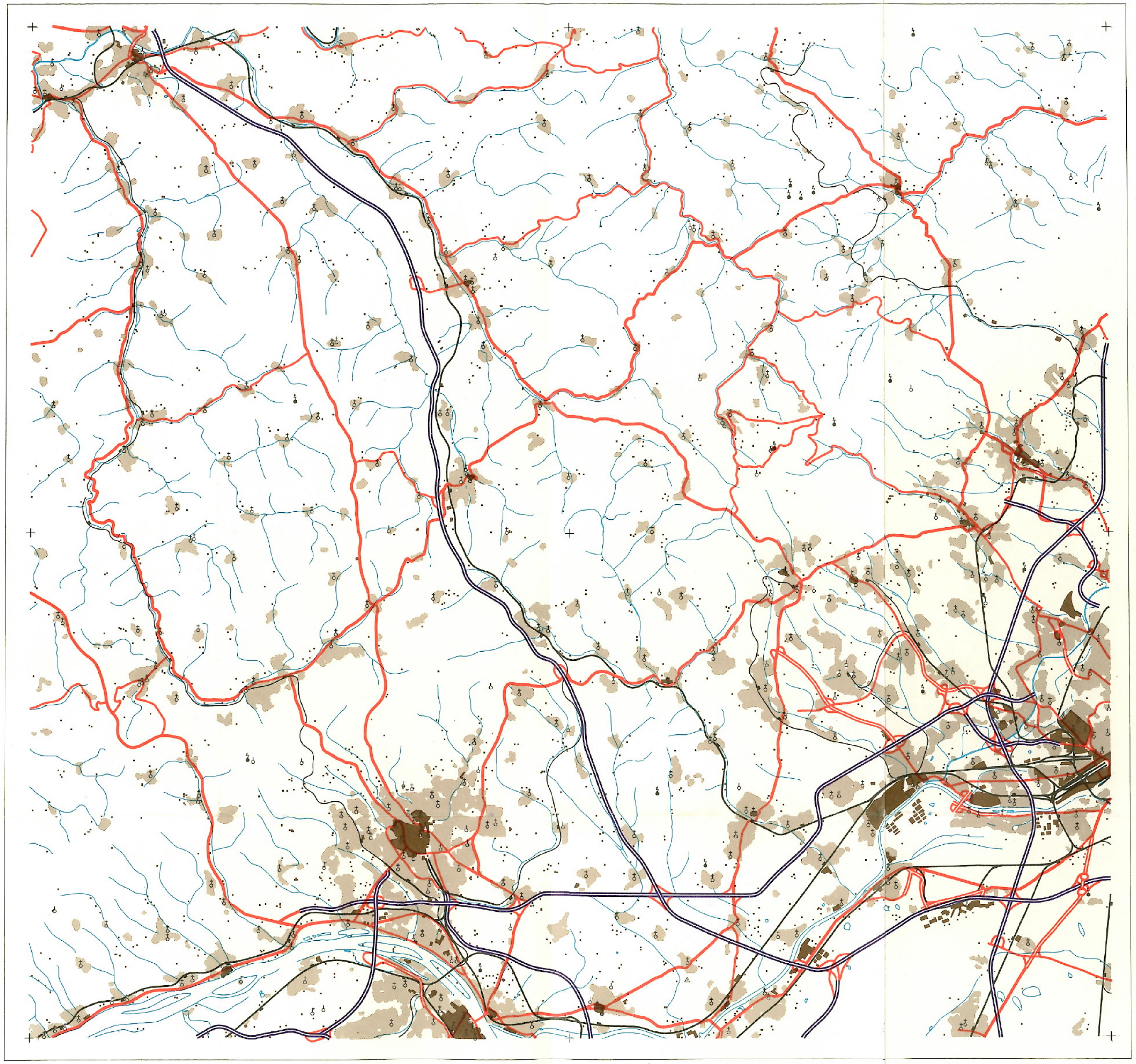
[8] *Uhrig, H.:* Preparation of Digitizing Manuscripts and Menu Display Supported Digitizing for a Small Scale Topographic Map. — Nachrichten aus dem Karten- und Vermessungswesen, Series II, No. 33, Frankfurt a. M. 1976.

F. Christ , Th. Johannsen , H. Uhrig

Annex 1
Nachrichten aus dem Karten- und Vermessungswesen , Serie II , No. 33

Intermediate test result:

Section of the general topographic map 1 : 200 000
sheet CC 6310 Frankfurt a. M. - West ,
full-automatically and semi-automatically generalized ,
edited and rim-adapted



Institut für Angewandte Geodäsie , Frankfurt a. M. 1976

Full automatically generalized ,
edited and rim-adapted contourlines.