GENERALIZATION OF THE GENERAL GEOGRAPHIC DATABASE[1]

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Abstract

As the National Geographic Information System and its components are developed in Poland (the components include: Topographic Database at 1:10 000 scale, Vector Map Level 2 at 1:50 000 scale, General Geographic Database at 1:250 000 scale) topicality of he generalization grows larger. Such conditions the need for creating a uniform spatial database out of which could be generated maps at various scales and for various purposes.

The authors' intention was to elaborate a Multi-resolution/representation database (MRDB) as a visualization of the General Geographic Database (GGD) at different resolution levels without a permanent loss of information. The selection of information depends not on durable data withdraw from a database but only on visualization of the generalized information adequately to resolution level. The visualization of the GGD was performed basing three levels: 1:500 000, 1:1000 000 and 1:4000 000. The scope of the study encompasses visualization of settlement layers as well as GGD transportation network within the area of two Polish provinces.

PURPOSE AND SCOPE OF STUDIES

The purpose of the study was to develop one spatial database out of the GGD (a digital landscape model at the basic scale of 1:250 000) and then to visualize various solutions on the basis of it). The assumption of the scientific project was to work out visualizations of the GGD at three scale levels: 1:500 000, 1:1000 000 and 1:4000 000 without a permanent loss of information. In this case the selection information depends not on data withdraw from a dataset but only on visualization of the generalized information – according to a particular resolution level.

The executed project is extremely important from the point of view of building spatial data infrastructure in our country. Having joined the INSPIRE initiative, Poland is required to provide the information society with wide-understood spatial data collected at different resolution levels. However, the purpose of the project is to define and then to assign a particular portion of information to a particular resolution level and what comes behind, to work out a methodology of generalization of the basic spatial data base GGD.

The scope of the studies covered carrying out two generalization experiments. The first experiment concerned the generalization of thematic layers –transportation network and settlement for the area of the Lower Silesia Province. The second experiment applied to the generalization of the same thematic layers in the Lodz Province. These researches have been a continuation of previous works concerning generalization possibilities of spatial databases (I. Chybicka, A. Iwaniak, W. Ostrowski, 2004).

GENERAL GEOGRAPHIC DATABASE

Being an essential component the National GIS, GGD represents a set of spatial data – which are the reference for the other data and objects. Therefore, the General Geographic Database makes it possible to identify other reference data and objects related to land cover and land use. It consists of the following thematic layers:

- administration zoning,
- settlement and anthropogenic objects,
- hydrography,

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- relief,
- transport,
- land covering and land use,
- protected and restricted areas,
- geographical names.

The study concerns both the layer of transportation network - which consists of railroads and roads - and that of settlement, including places, represented by either signatures or signatures and contours – in case of larger towns.

GENERALIZATION TOOLS

To perform both experiments a commercial software has been used. The authors chose GeoMedia - a complex application which is designated for performing advanced spatial analysis and – DynaGEN - a specialist system supporting the generalization process. Both are the products of Intergraph corporation.

The DynaGEN environment

During execution of the project a model of R.B. McMaster and K.S. Shea was used. More information about this model as well as functionality descriptions of the postulated generalization operators and algorithms can be found in the work of A. Iwaniak., W. Paluszynski, W. Zyszkowska, (1998). In this model the idea of generalization operator was defined either as an elementary map transformation, which can be expressed by a mathematic formula or as an unambiguous procedure description (an algorithm). Such a transformation can be named as a generalization step.

The computer generalization process can be defined as a sequence of such transformations with given particular parameters. Such a sequence and its parameters must be matched in a way that fulfills some conditions and relations between generalized objects.

In the generalization process, a cartographer has at his/her disposal a number of operators, algorithms and parameters (simplify, smoothing, aggregation, collapse, boundary extend, typify, square angles and object merge), whose application depends on a kind of generalized object.

The GeoMedia system

GeoMedia is an advanced GIS environment designated for integration of different geographic data originating from various sources, stored as different formats, presented in different coordinate systems. Both geographic and descriptive data are stored in a common database. The functionality of the system makes it possible to perform complex spatial and attribute analyses. GeoMedia allows the user to create dynamic services - for example GGD visualized on different resolution levels. The system can also be described as open - it means that GeoMedia makes it possible to implement one's own procedures and subprograms. From the utilitarian point of view the most essential feature is the possibility of performing sophisticated spatial and attribute analysis related to the GGD.

THE GENERALIZATION OF A TRANSPORTATION NETWORK AND SETTLEMENT

The operations forming the generalization process may be classified in different ways. The authors agree with the concept of dividing the process into the data model generalization and the cartographic generalization proposed by M. Bell, D. Neuffer, P. Woodsford (2004).

The data model generalization makes it possible to reduce the number of data in relation to the assumed resolution level. It covers the following actions:

- selection of whole feature classes,
- selection of object components from a particular feature class on the basis of attribute and spatial conditions,
- change of object's geometry types (way of presentation and method of object's presentation),
- geometry simplification.

The role of cartographic generalization as a stage following the data model generalization is obtaining of the optimal map legibility at a given scale. The cartographic generalization process consists of:

- application of proper data symbology,
- shifting of objects; aggregation; changing of object's dimensions.

The authors focused on the first stage of the generalization process (connected with the data model generalization). The selection of the map content took for visualization on particular resolution degrees was performed on the basis of analysis of existing geographic maps as well as interviews with experts in the field of generalization. Ordering the map content to the visualization performed for each of the scales (1: 500 000, 1: 1M and 1:4M) covered performing proper spatial and attribute analyses in the GeoMedia system. The operations connected with the simplification and objects' smoothing were performed in the DynaGEN application. This process encompassed a simplification of routes and their smoothing as well as the simplification and smoothing of buildings' contours.

Generalization of transportation network and settlement for particular scale levels

The generalization of a transportation network and settlement covered performing of sequential generalization steps. Below the authors described basic generalization steps which are part of the generalization of both transportation network and settlement for particular scale levels. The activities connected with the use of advanced attribute and spatial analyses were performed in the GeoMedia environment for the sake of a wide range of available tools. However, all actions related to the simplifying and smoothing of objects have been carried out by using the DynaGEN software which includes a rich set of generalization operators.

The generalization process of the transportation network was preceded by the preliminary data preparation. It consisted in combining smaller road segments (obtained as a result of digitizing) into bigger continuous objects used in an interactive generalization. This task was performed in the DynaGEN software, whose operator made it possible to join object elements into the network structures (*feature blending, merging*). The criterion of joining objects is constituted by the same attribute value related to the number of an international road and a department managing this road (Province, District, Community). The process was carried out automatically. The next steps concerning the generalization of vehicle- and railroads were performed in an interactive mode.

When generalizing settlement areas, the authors needn't execute a preliminary data processing. Hence, the following generalization steps were performed exclusively in the interactive mode.

Generalization activity undertaken to visualize data at the resolution level representative for the 1:500 000 map scale.

The visualization process at the resolution level characteristic for the 1:500 000 map scale was performed by executing the following generalization steps (table 1):

Generalization step	Description of a generalization step	Criterion	Implementation		Notices
			GeoMedia	DynaGEN	
1	Selection of settlements represented by signatures	Presenting cities and government seats of a province, district or community	Attribute queries	-	-
2	Selection of roads	Selection of national, province and district roads; rejection of communal and private or factory roads; by attribute values	Attribute queries	-	-
3	Selection of railroads	Selection of a railway type; rejection of narrow-gauges and inactive railways; by attribute values	Attribute queries	-	-

4	Selection of settlements presented by contours	Presenting contours whose area is larger than 9 mm^2 in a map scale as well as cities and seats of province and district governments.	Area calculation by applying the Functional Attribute; Object selection – Attribute Query		
5	Road simplification	-	-	Operator: ‘Simplify’; Algorithm: ‘Douglas’; Tolerance parameter’s value = 0.15	-
6	Road smoothing	-	-	Operator: ‘Smooth’; Algorithm: ‘Simple Average’; The ‘Look Ahead’ parameter’s value = 3	-
7	Railroad simplification	-	-	Operator: ‘Simplify’; Algorithm: ‘Douglas’; Tolerance parameter’s value = 0.35	-
8	Railroad smoothing	-	-	Operator: ‘Smooth’; Algorithm: ‘Simple Average’; The ‘Look Ahead’ parameter’s value = 3	-
9	Simplification of the settlement’s contour	-	-	Operator: ‘Simplify’; Algorithm: ‘Area Preservation’ The ‘Area Change Allowed’ parameter’s value = 0.15	-

10	Smoothing of the settlement's contour	-	-	Operator: 'Smooth'; Algorithm: 'Simple Average'; The 'Look Ahead' parameter's value = 1	-

Table 1Generalization steps for the 1:500 000 map scale

Generalization activity undertaken to visualize data at the resolution level representative for the 1:1000 000 map scale.

The visualization process at the resolution level characteristic for the 1:1 000 000 map scale was performed by executing the following generalization steps (table 2):

Generalization step	Description of a generalization step	Criterion	Implementation		Notices
			GeoMedia	DynaGEN	
1	Selection of settlements represented by signatures	Representing cities and government seats of a province, a district. Rejection of community seats.	Attribute queries	-	Change of the object presentation method from contour to signature for cities, seats of provinces and districts.
2	Selection of roads	Selection of national and province roads; rejection of district roads; by attribute values.	Attribute queries	-	-
3	Selection of settlements represented by contours	Representing contours, whose area is larger than 9 mm^2 in a map scale.	Area calculation by applying the Functional Attribute; Object selection – Attribute Query	-	-
4	Road simplification	-	-	Operator: 'Simplify'; Algorithm: 'Douglas'; Tolerance parameter's value = 0.20	-

5	Road smoothing	-	-	Operator: 'Smooth'; Algorithm: 'Simple Average'; The 'Look Ahead' parameter's value = 3	-
6	Railroad simplification	-	-	Operator: 'Simplify'; Algorithm: 'Douglas'; Tolerance parameter's value = 0.35	-
7	Railroad smoothing	-	-	Operator: 'Smooth'; Algorithm: 'Simple Average'; The 'Look Ahead' parameter's value = 3	-
8	Simplification of the settlement's contour	-	-	Operator: 'Simplify'; Algorithm: 'Area Preservation'; The 'Area Change Allowed' parameter's value = 0.25	-
9	Smoothing of the settlement's contour	-	-	Operator: 'Smooth'; Algorithm: 'Simple Average'; The 'Look Ahead' parameter's value = 1	-

Table 2 Generalization steps for the 1:1000 000 map scale

Generalization activity undertaken to visualize data at the resolution level representative for the 1:4000 000 map scale.

The visualization process at the resolution level characteristic for the 1:4 000 000 map scale was performed by executing the following generalization steps (table 3):

Generalization step	Description of a	Criterion	Implementation	Notices

	generalization step		GeoMedia	DynaGEN	
1	Selection of settlements represented by signatures	Representing by signatures cities that were represented by contours at the 1:1000 000 scale	Attribute queries	-	Change of the object presentation method from contour to signature for settlements presented as contours at previous scale.
2	Selection of roads	Selection of national roads; rejection of province roads; by attribute values.	Attribute queries	-	-
3	Road simplification	-	-	Operator: 'Simplify'; Algorithm: 'Douglas'; Tolerance parameter's value = 0.30	-
4	Railroad simplification	-	-	Operator: 'Simplify'; Algorithm: 'Douglas'; Tolerance parameter's value = 0.40	-
5	Railroad smoothing	-	-	Operator: 'Smooth'; Algorithm: 'Simple Average'; The 'Look Ahead' parameter's value = 3	-

Table 3 Generalization steps for 1:4000 000 map scale

VISUALIZATION OF THE GGD AT ASSUMED RESOLUTION LEVELS

The final visualization of the generalized data was performed in the GeoMedia system. The figures below (figures 1 – 4) present the generalization results and effects of selecting map contents according to the particular resolution levels.

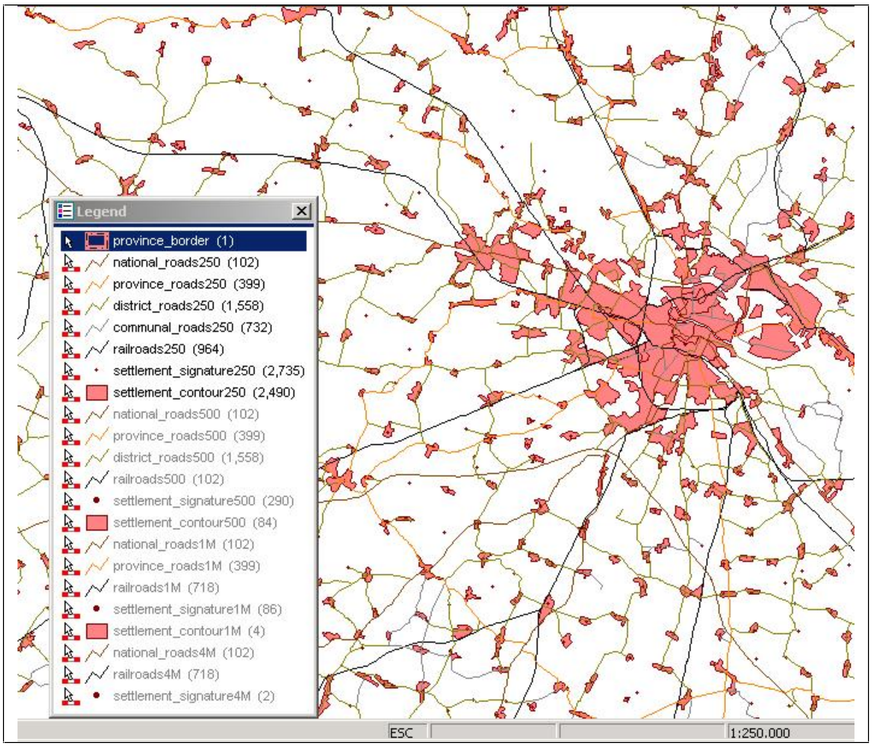

Figure 1 Visualization of the GGD at the scale of 1:250 000 (the province of Lower Silesia)

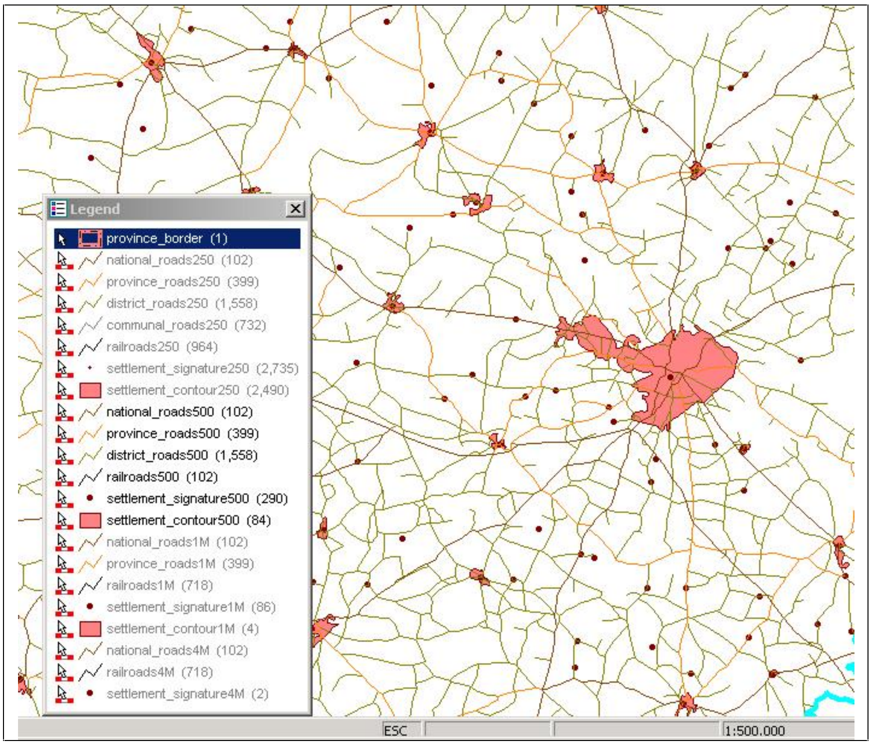

Figure 2 Visualization of the GGD at the scale of 1:500 000 (the province of Lower Silesia)

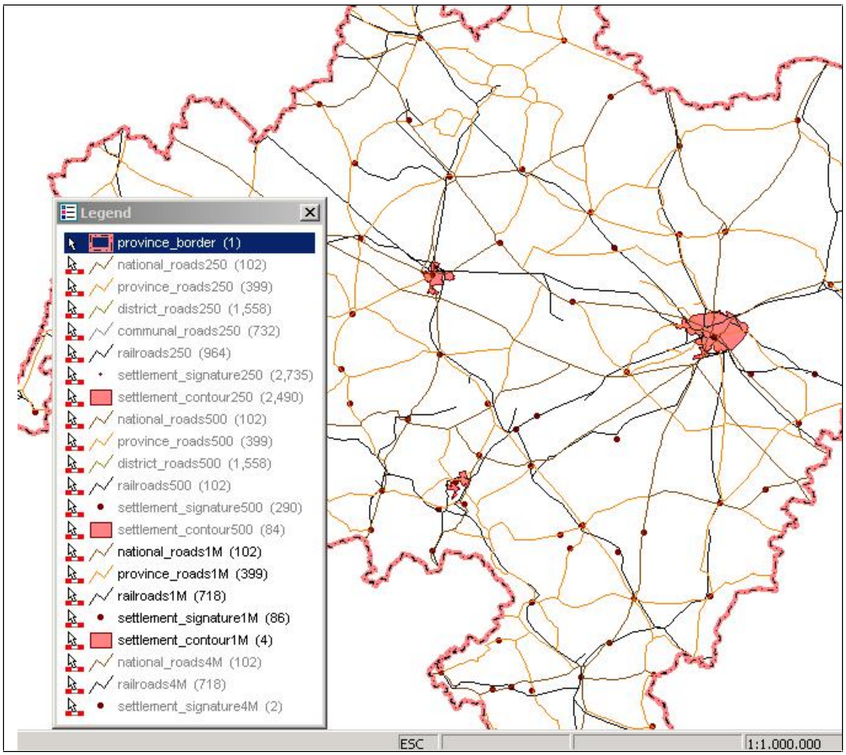

Figure 3 Visualization of the GGD at the scale of 1:1000 000 (the province of Lower Silesia)

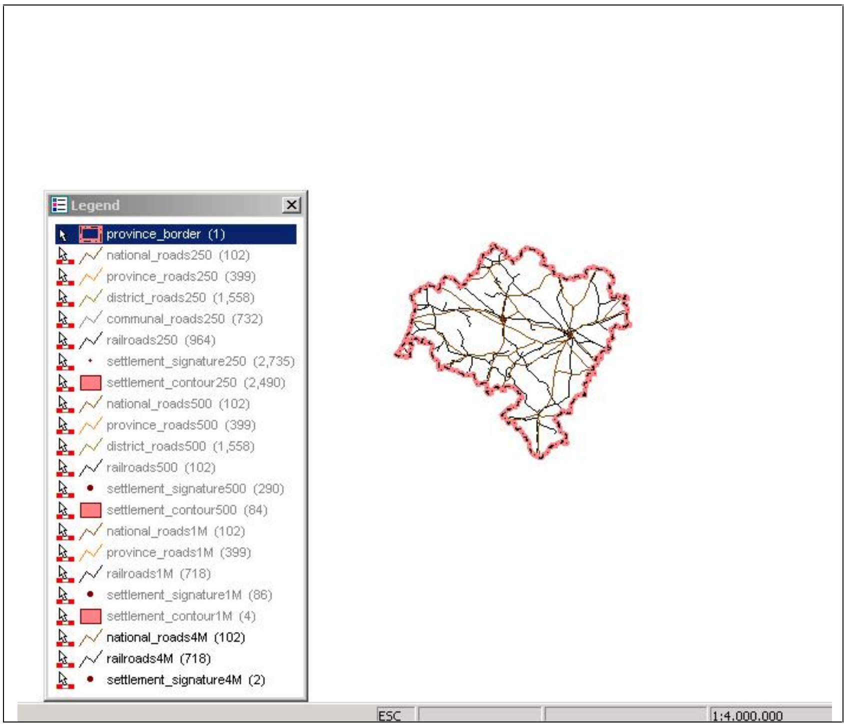

Figure 4 Visualization of the GGD at the scale of 1:4000 000 (the province of Lower Silesia)

CONCLUSIONS

Based on the performed experiments, the following conclusions can be drawn:

- A generalization carried out at small scales is very subjective and in most cases it is a very intuitive process. Therefore, there are no precise instructions concerning a redaction of small scale maps.
- The generalization at these scales has a context character but less then during a generalization of topographic maps at medium scales. In the DynaGEN software there is no possibility of context generalization in an automatic mode however, it is possible to determine a series of helping factors in GeoMedia. The factors make it possible to solve appearing problems.
- The formalization and hence automation of the generalization process of such studies is a very difficult task. In the presented project the authors propose a sequence of generalization steps that have been experimentally selected out of a wide range of operators and generalization parameters tested before.
- Furthermore, from the point of view of contemporary achievements in this subject, described in literature, working out of maps at these scales requires a lot of other generalization criteria to be taken into account. However, the scope of the project was a determination of GGD's generalization possibilities based on available information as well as obtaining repeatable, objective results.
- As the experiment was carried out a number of difficulties provoked by the lack of precise tools for spatial analysis were found. This problem must be pointed out to be resolved in the future by developing one's own tools adjusted to particular graphic cases.

The results presented in this paper are an attempt to determine automatic generalization of the GGD digital landscape model. Further research and trials on generalization of the following GGD elements will certainly develop the knowledge base on the generalization process as well as its more efficient automation and simplification. All the tests performed for this purpose are very important in connection with research on the possibilities of the proposed models, and on the further development of new generalization methods of small scale maps.

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