Generalization of the Topographic Database to the Vector Map Level 2 – the components of the Polish National Geographic Information System

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Objective and scope of the elaboration

The objective of the elaboration is the cognition and description of a generalization process of the Topographic Database (detail corresponding to the topographical map in the scale of 1:10,000) to the vector map level 2 (VMap Level2 in the scale of 1: 50,000). Cognition of generalization principles has been used to construct a knowledge base in the software environment DynaGEN by Intergraph.

The correctness of the elaborated knowledge base was verified by conducting two experiments. The first experiment concerned generalizing the TBD thematic layers – transportation networks and buildings - within the area of Warsaw –in the town of Lomianki. The other one was – generalizing the thematic layer of the transportation network in the surroundings of Kowalewo Pomorskie. The experiments concerning generalization are a continuation of the work on topographic maps generalization from the scale of 1:10000 to 1:50000 (A. Iwaniak, W.Paluszynski 2003).

VMAP2 and TBD are components of the national geographic information system. Both components are complex products consisting of both DLM (Digital Landscape Model) and DCM (Digital Cartographic Model). The purpose of the experiment, is the generalization of the DLM of topographical data base to the DLM of the Vector Map Level 2.

VMAP2

The Vector Map Level 2 was elaborated by the Military Geography Section of the Polish Army General Staff and produced under a national initiative. Its detail resolution corresponds to a 1:50,000 scale. The contents of this product are defined by a conceptual pattern comprising 110 classes of objects grouped in nine functional subject layers. Its degree of information completeness is conditioned by access to reliable source materials attainable during the data introduction stage. Original elaboration as regards power engineering and railways systems were used for the area of Poland as the principal material, apart from the 1:50000 scale map. The "Atlas of Polish Lakes" published by the Meteorological and Hydrological Institute was also used in this work. The present state of legislation as regards road classification, administrative division and protection of classified information was also taken into consideration. Restricted access to specialist data held by individual trade institutions also had substantial influence on the restricted degree of completeness of available attributes.

A system of spatial references, distribution format and manner of encoding semantic features are identical for all NATO standard products, including Vmap2. The remaining elements of the vector products standard specified by the Digital Geographic Information had Group (DGIWG). The Vmap2 standard distribution format is VPF, the theoretical ground for which is the second part of DGIEST; "Theoretical Model Exchange Structure and Encapsulation Specification".

Topographic Database

"Topographic Database (TDB) is the official name of a conceptually cohesive national system for collecting, managing and accessing topographical data, functioning under appropriate legal regulations. The term "Topographic Database" comprises data resources, an IT management system and also an appropriate financing and organizing system. Its information and functional scope as well as its technological quality are defined by appropriate technical recommendations and instructions.

TDB is understood as the source of data of a new quality compared with present topographic maps which are the outcome of the evolution of data-winning and -management methods. The TDB creation process should be reviewed in the context of continuation of the achievements registered by Polish topographic cartography. The TDB model has been designed on the basis of cognitive machinery of contemporary topography and centuries-long experience in this discipline as regards choreography. The topographic database will constitute an essential element in the National Land Information System, in the widest sense of the term."

Generalization model

Experiments were performed using Intergraph commercial software – DynaGEN and Dynamo. DynaGEN is an application functioning as a subsystem of Dynamo, which means it allows the use of graphical environment, topological functions, and data models of Dynamo. The program offers two modes of operations: the batch mode (automatic), the assisted mode (under a human cartographer's supervision). The system offers a "dynamic" operation, which means the operator can change any parameter values using sliders, and visually inspect the dynamically changing results. A concept of the generalization operator was defined as elementary map conversion (transformation) which can be expressed either by mathematical formula or by unequivocal procedure description (algorithm). Such conversion can be termed the generalization step. The process of computer generalization can be used as a sequence of such conversions adding values of particular parameters. This sequence and its parameters must be selected in a way to maintain certain parameters and the relations between generalized objects. During the generalization process, depending on the type of generalized object, a cartographer has access to wide scope of operators, algorithms and generalization parameters. In the DynaGEN system there are available such operators as: simplifying, smoothing, aggregation, changing the presentation of objects, extending borders, selecting representative objects, angle straightening and joining objects.

Constructing a knowledge base

The implementation of generalization principles in the DynaGEN environment is connected with constructing a knowledge base (stored as the Access format) containing:

- List of principles describing specific generalization steps including:
    - the name of a generalized object,
    - the operator,
    - the algorithm,
    - the values of algorithm parameters,
    - a name and values of attributes referring to objects created as a result of generalization ,
    - a condition of implementing the particular method.
- description of prohibited topological changes (describing prohibited spatial relations between generalized objects).

The knowledge base in the DynaGEN system contains two sets of principles. The first one, containing rules executed in an automatic mode and in a restricted sequence, serves as preliminary data preparation. The second set contains principles describing fundamental generalization processes executed interactively and supervised by a cartographer which decisive for the sequence of application.

Generalization of roads and built-up areas

In order to recognize generalization processes the following materials were used:

- existing technical instructions describing principles of topographic maps editing in the scale of 1:10000 and 1:50000,
- analysis of topographic maps in the scales 1:10000 and 1:50000,
- interviews with cartographers – the experts of generalization ,
- practical experience from experiments performed in the DynaGEN environment.

Generalization of a road network consists of two stages. The first one relies on the analysis and preliminary data processing. The scope of this process comprises the building of a hierarchical model of a road network and joining the road segments together over the whole area. Final criteria of joining road segments are: equality (conformity) of selected parameters describing attributes or angular values between roads. The second one is a mean generalization process and comprises the following generalization steps:

Quantity generalization of surfaced roads:

- selection of parallel roads; operator 'Typify Lines', algorithm 'Conflict Resolution', a value of default parameter 'Minimum Spacing Tolerance' - 7,5 mm.
- rejection of blind-alleys, searched by the spatial query.
- simplification of the routes of surfaced roads, operator 'Simplify', algorithm 'Douglas Global Tolerance Band' value of tolerance parameter =0.05.

Quantity generalization of unsurfaced roads:

- rejection of segments of unsurfaced roads – "hanging",
- rejection of short access roads,
- selection of representative unsurfaced roads,
- simplification of the routes of unsurfaced roads, operator 'Simplify', algorithm 'Douglas Global Tolerance Band' value of tolerance parameter =0.05.

Quantity generalization of paths:

- selection of representative paths,
- simplification of the routes of paths, operator 'Simplify', algorithm 'Douglas Global Tolerance Band' value of tolerance parameter =0.05.

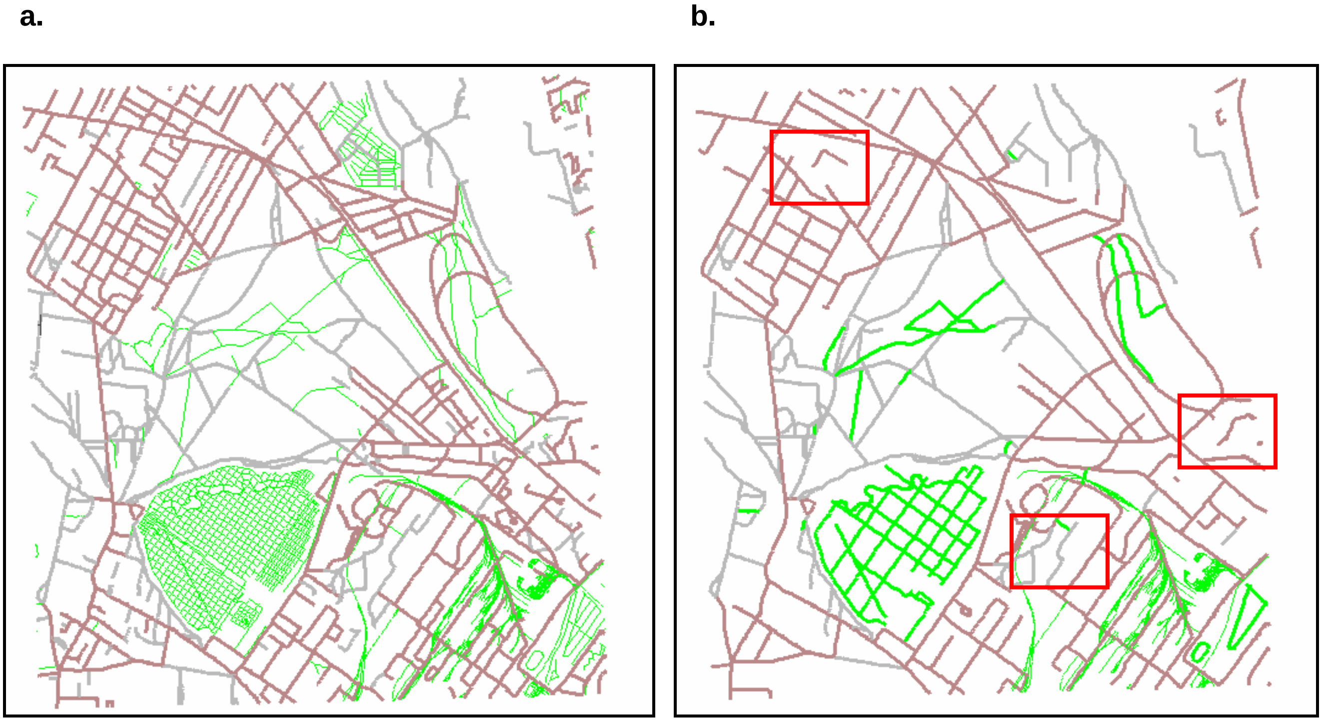

Fig1. Generalization of transportation network a. output data b. results and places where errors appeared – experiment 1.

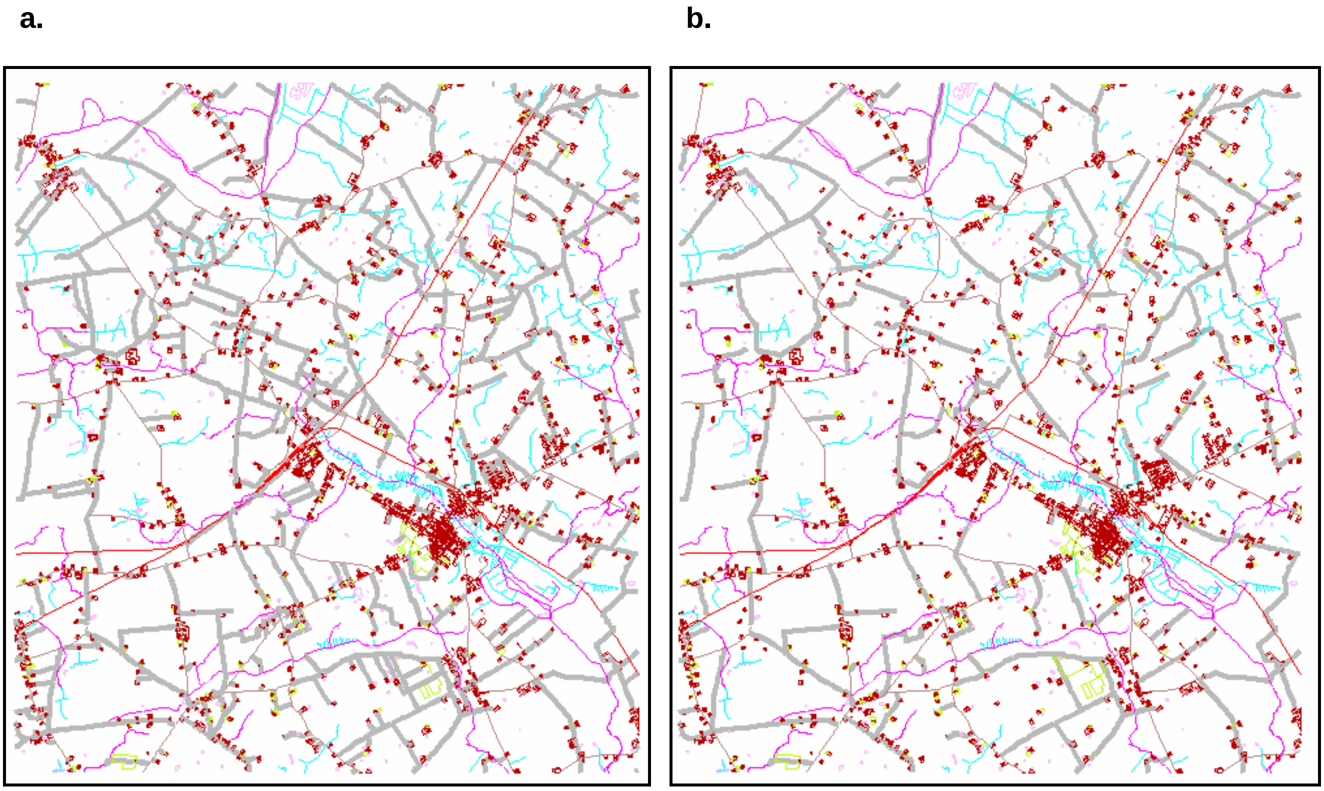

Fig2. Generalization of transportation network a. output data b. results – experiment 2.

a. b.

Fig3. Generalization of built-up areas a. output data b. results – experiment 1.

The generalization of built-up areas runs on one stage – it means there is no need to execute previous data processing. The scope comprises the following generalization steps:

- aggregation of adherent or closely-situated built-up areas,

  - connection of built-up areas - making possible the aggregation of adjacent built-up areas to the created built-up areas using the 'Aggregate Areas' operator; the algorithm 'Adjoining',

  - the areas which are not adjacent to each other but situated within a distance smaller than 5mm (50m) with at least two one-family houses will also be added. Built-up areas fulfilling the mentioned condition have been selected using dynamical query (the number of houses within the particular area has been counted) and furthermore, by using the operator 'Aggregate Areas', additional areas will be joined to the areas created in the previous step (the algorithm 'Orthogonal'; default parameters value set to 5mm).

  - built-up areas which were not joined to the selected areas but still covering the minimal number of two one-family houses and situated within a distance of 5 mm from each other, will also be aggregated. Such operation will be performed with the use of the 'Aggregated Areas' operator, the algorithm 'Orthogonal', the value of 'Threshold Tolerance' is equal to 5mm.

- selection of representative farmsteads (concerns farmsteads situated near orchards), these farmsteads have been chosen with a query,
- extending the borders of built-up areas to neighboring objects, operator Extend, algorithm Areas To Line, Areas. The parameters values individually adjusted in the following ranges: Threshold Tolerance 0.10 – 0.20 mm, Zone Tolerance 0.10 – 0.20 mm.

Limitations and problems

- Any universal choice of operators for the whole area is impossible. Selection of operators proposed in the work has been a compromise. In most cases, they deliver proper results but there are errors also happened, originating in the principal nature of the generalization process and from operators implemented in the DynaGEN system,
- taking into account a significant changeability of parameters of particular algorithms, the values of parameters should be suited to a particular geographical situation and the result should be controlled by the operator,
- field roads, which are extensions of surfaced roads are identified by the system as ‘hanging’ and, finally rejected. Probes of joining roads bring however much worse results,
- in some specific cases, the connections of a road are rejected. The road become a separate segment, as a result of the executing of ‘Typify Lines’ operator. An example can be the situations presented on the figure 1,
- after the use of the ‘Extend Boundary’ operator, the area of boundaries require minor manual corrections.

Conclusions based on the results of the experiment

The performed experiments allow the following concluding remarks to be made:

- The DynaGEN system is a universal and advanced tool which supports a map’s generalization process. Thanks to its whole gamut of operators and generalization parameters it delivers a coherent methodology for the entire process and significantly reduces the time of map elaboration.
- Generalization operators available in the system ‘DynaGEN’ concern not only object geometry but also the topological relations between them. For example, during the process of lines simplifying the proximity of other objects is taken into account.

Before (or during) the generalization process a possibility exist of declaration of fault spatial relations (Disallowable Topological Changes). Such an approach makes possible constant analysis and maintaining spatial relations between objects during the generalization process. Thanks to that, proper map topology is substantiated.

- Considering the complexity of the generalization process, it can be said that at this stage of knowledge, the ability to fully automate the process, within the current environment is impossible.
- The lack of precise and unequivocal definitions of objects both in TBD and in the VMapL2, as well as the lack of instructions to the VMapyL2 which describe generalization principles and map redaction is a factor which makes the process much more difficult. Due to this, all the necessary data were obtained from the analysis of existing maps. Unfortunately, they are characterized by a lack of consequence and a significant amount of subjectivity by the authors.
- In the generalization process, the most important factor is the method of data preparation. For example, generalization of a transportation network demands constructing an hierarchical data model.
- A solution which is planned is construction of a database on the platform of 'Oracle Spatial'. This makes an access to the data possible both in the program 'Dynamo' (module 'FLDB'), the application 'GeoMedia' and the system 'Oracle' by creating scripts in the PLSQL. For example, the search for hanging field roads in the 'Dynamo' environment was complicated while, in GeoMedia the task is very easy to perform.
- The aim of the experiment is a maximal automation of generalization process, the solving of spatial conflicts and difficult cases. Because of that, it would be very helpful if in the system 'DynaGEN':
    - The values of generalization algorithms could also stand a value of describing attributes of the generalized objects.
    - The possibility of overtaking a program maintenance (executed by a special macro) in the moment of appearance of fault topological changes would also be very demanded.

Further research and trials on generalization of the following TBD elements will certainly develop the knowledge base connected with 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.

References

- Iwaniak A., Paluszyński W., 2003, Implementation of a knowledge database for the generalization of topographic maps in GIS systems, Proceedings of the 21st International Cartographic Conference, Durban, RSA.