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Automatic Generalization of Cartographic Data for Multi-scale Maps Representations

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Abstract. The multi-scale base map compiled from the official 1:10 000 framework data is served as the background in the national geoportal map browser. High expectations of the users of this map – both up-to-datedness and comfort of use – are pressing to search for more efficient methods to generate it preserving highest cartographic quality. There are two ways towards that: (a) automated generalization of the georeference base dataset into smaller scale datasets that are then used as sources for the multi-scale web map and (b) automated cartographic generalization of the single source dataset into multi-scale map layers (used in Lithuanian geoportal). As it is commonly believed that generation of Web map layers from separately generalised data sources is more appropriate, the authors performed a research in order to compare the two methods in terms of precision of representations, efficiency of update and communicative quality of the resulting maps. Some procedures that allow for improvement of visualization quality when the second method is used are discussed in the paper. The main conclusion drawn from the research is that a multi-scale map generated by means of cartographic generalization can for many applications successfully replace multi-scale map generated from separately generalized data sources.

Keywords: multi-scale map, generalization, automation, geoportal.

Conference topic: Technologies of geodesy and cadastre.

Introduction

The paper represents the results of experimental research conducted by the developers of the portal of Lithuanian Spatial Data Infrastructure. Due to user-friendly cartographic visualization and some data enhancements this map service is also widely used in numerous other information systems and applications in Lithuania. The use of map web services at the portal of Lithuanian Spatial Data Infrastructure *Geoportal.lt* (Lithuanian Spatial Information... 2017) had been growing from several thousands in 2010 to more than two millions in 2016 and further increase of use is expected. The goal of the research was to evaluate different methods of regular update of the base map service of the *Geoportal.lt*. The data for the map and cartographic representation are updated every month. Therefore it is important to reduce the costs of updating without losing in quality of map communication.

Two generalisation methods were compared during numerous experiments:

– automated generalization of the (geo)referential spatial dataset into smaller scale datasets that are then used as sources for the multi-scale web map (ADG) as well and
– automated cartographic generalization of the single source dataset into multi-scale map layers (ACG).
– The aspects of comparison included:
– precision of representations,
– efficiency of update and
– basic communicative quality of the resulting maps.

The authors focused mainly on production of maps at scale 1:50 000 and compared generalization methods ant procedures, required qualifications and number of man hours needed to achieve satisfactory outcome. Similar principles of generalization are applied to the smaller scales.

Map data sources

Usualy topographic base maps at different map scales or base web map layers include information on natural and man-made real objects: geodetic network points, relief, hydrography, land cover, transport network (e.g. road network and supporting constructions, railways), engineering networks, settlements, boundaries of administrative units, protected areas etc.

In Lithuania the primary dataset for topographic maps and base web map of *Geoportal.lt* is national dataset of (geo)referential spatial dataset designed at reference scale 1:10 000 GDR10LT. This spatial dataset is continuously updated from several official sources (Papšienė *et al. 2014*):

- newest available ortophotographic maps at scale 1:5 000 or 1:10 000;
- geodetic and cartographic reference data;
- data from related State cadastres and registers: address register, hydrography cadastre and road information system;
- field measuremens;
- crowdsourced data: updates from the users of the dataset (mainly on changes or errors).

The derived dataset at scale 1:50 000 GDR50LT is designated for use for smaller scale maps. The GDR50LT dataset was updated manually until 2014. The whole process lasted up to 2–3 years (Papšienė 2014) and approximately 20–30 cartographers were involved in the update of spatial data. Since 2014, this dataset is updated automatically from the GDR10LT and other data sources. The technology for automated generalization and upload have been developed at the State Enterprise "GIS-Centras" during project "The automatization of (geo)referenced spatial dataset at scale 1:50 000 GDR50LT". The project was financed by the National Land Service under the Ministry of Agriculture (NLS). The main benefit of the project is developed methodology of automation that allowed for essential reduction of resources necessary for update. The dataset is compliant with the updated specification and it is efficiently generated on demand. Manual work may be necessary for specific improvements where the automation fails, but it is minimized. Now, the GDR50LT can be updated within 2 months.

Topographic and base maps

Topographic map TOP50LKS is middle scale map designated for both orientation and overview. This scale is considered best for planning, military operations, tourism etc. It is also used as the background for production of diverse thematic maps and thematic spatial datasets where 1:10 000 scale data is too detailed and create clutter when represented. This broad purpose map is compiled from several data sources:

- automatically updated GDR50LT;
- additional data sources form state cadastres, registers and information systems that do not feed GDR50LT;
- additional information collected by the developer.

Since 2016, this topographic map is prepared automatically as well. The technology for automated generalization and preparation of cartographic product have been developed at the State Enterprise "GIS-Centras" during the project "Preparation of topographic map of Republic of Lithuania at scale 1:50.000 (TOP50LKS, TOP50LKS-SR)". The project was financed by the NLS.

TOP50LKS map uses intermediate (cartographic) database that facilitates representation of specified conventional signs (Fig. 1).

Geoportal.lt base map GBM is a multi-scale map designed for electronic use in form of map service. It is created automatically from GDR10LT spatial data, which is symbolised in *ArcMap* document file (.mxd), were the data is arranged into layers groups by different scales (e.g. 1:2 000, 1:5 000, 1:10 000 etc.). Map objects are represented with point, line, polygon symbols and labels. The number and values of scale used in the *Geoportal.lt* map viewer (www.geoportal.lt/map) depend on those used in the multi-scale map, therefore the scale values must be thoroughly planned. For large scale data layers, supplementary information, such as sport territories and stadiums, and driveways in residential districts, was imported from additional geodatabases (Fig. 1).

The GBM map is used by about 11000 registered *Geoportal.lt* users and by even larger number of users of many information systems to which GBM service is provided. High user expectations are put on this map – up-to-datedness, good cartographic quality and comfort of use when navigating through its layers. In this research we focused on 1:50 000 layers that are comparable to the TOP50LKS.

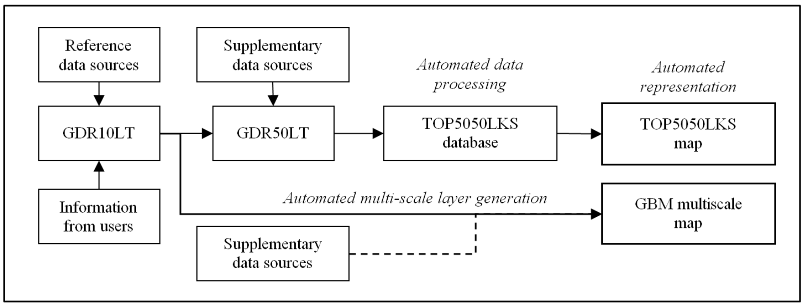

Fig. 1. Data flows for design of TOP50LKS and GBM maps

Framework for comparison of map generalization methods

During generalization of spatial datasets and maps, appropriate sequence of works is important for obtaining cartographically correct outcome. Cartographic generalization for internet maps includes several steps (Roth *et al.* 2011):

1. generalization of content, that includes selection of features by their qualitative and quantitative characteristics;
2. appropriate ordering of information layers;
3. graphical generalization by means of cartographic representation (e.g. simplification; employment of graphic variables to reflect different types of relationships) and
4. selection and smart placement of labels.

The authors followed these steps using *ESRI ArcGIS Server* technology. Due to choice of technology possibilities of automated placement of labels were limited. There are plans to improve it in the nearest future.

Generalization methods that are applied in cartography describe abstract data transformations. Over the long period of development of generalization methods, there is no uniformly adopted ontology of the methods. Different researchers base their classifications on needs and outcomes of their research (Beard, Mackaness 1991; McMaster, Shea 1992; Ruas, Langrange 1995). Therefore, for comparison of ADG and ACG methods, two taxonomies of generalisation methods were used:

1. common generalisation methods (by Berliant 2003) and
2. technical generalization operations (by Bader *et al.* 1999; Cecconi 2003).

The use of known generalization methods for the experiment is summarized in Table 1 and Table 2.

Table 1. Generalization methods used for design of TOP50LKS map and for GBM 1:50 000 scale layers (classification by Berliant 2003)

Principle of generalization	**Used generalization method**	
	ADG (fully automated data generalization)	**ACG (generalization of cartographic representation)**
Theoretical generalization method		
Qualitative generalization	Performed	Performed
Quantitative generalization	Performed	Performed
Conceptual generalization	Performed	Partial or none
Selection of features by selection census	Performed	Performed
Selection of features by sampling rate	Performed	Partial or none
Cartographic generalization	Performed	Partial depending on the specifics of features
`Combination of contours	Performed	Partial depending on the specifics of features
Placement shift	Performed	Not performed
Enlargement of features	Performed	Partial depending on the specifics of features

Table 2. Generalization methods used for design of TOP50LKS map and for GBM 1:50 000 scale layers (classification by Bader *et al.* 1999; Lamy *et al.*1999; Cecconi 2003)

Principle of generalization			**Used generalization method**	
			ADG (fully automated data generalization)	**ACG (generalization of cartographic representation)**
1			**2**	**3**
Technical generalization method				
Attribute transfor-mation	Classification	Thematic Selection	Performed	Performed
		Thematic Aggregation	Performed	Performed
Spa tial tran / In-divi dua	Simplification	Weeding	Performed	Not performed

End of Table 2

<table>
<tr><td colspan="6">1</td><td>2</td><td>3</td></tr>
<tr><td rowspan="14"></td><td rowspan="7"></td><td colspan="2"></td><td colspan="2">Unrestricted simplification</td><td>Performed</td><td>Partial or none</td></tr>
<tr><td colspan="4">Collapse</td><td>Performed</td><td>Partial or none</td></tr>
<tr><td rowspan="2">Enhancement</td><td rowspan="2">Regarding geometric constraints</td><td colspan="2">Enlargement</td><td>Performed</td><td>Partial or none</td></tr>
<tr><td colspan="2">Exaggeration</td><td>Performed</td><td>Not performed</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">Regarding semantic constraints</td><td colspan="2">Smoothing</td><td>Performed</td><td>Partial or none</td></tr>
<tr><td colspan="2">Fractalization</td><td>Performed</td><td>Not performed</td></tr>
<tr><td colspan="2">Rectification/Squaring</td><td>Performed</td><td>Not performed</td></tr>
<tr><td rowspan="3">Objects and groups</td><td rowspan="2">Selection/ Elimination</td><td colspan="3">Selection</td><td>Performed</td><td>Performed</td></tr>
<tr><td colspan="3">Elimination</td><td>Performed</td><td>Performed</td></tr>
<tr><td colspan="4">Displacement</td><td>Performed</td><td>Not performed</td></tr>
<tr><td rowspan="4">Object groups</td><td rowspan="4">Aggregation</td><td rowspan="3">To a single object</td><td rowspan="2">Amalgamation</td><td>Smoothing</td><td>Performed</td><td>Not performed</td></tr>
<tr><td>Merge</td><td>Performed</td><td>Partial or none</td></tr>
<tr><td colspan="2">Combination</td><td>Performed</td><td>Not performed</td></tr>
<tr><td>To multiple objects</td><td colspan="2">Typification</td><td>Performed</td><td>Not performed</td></tr>
</table>

The research was conducted during implementation of several projects funded by the national programmes: “Feasibility study of updating the (geo) reference spatial data set of the Republic of Lithuania at scale 1:50.000 (GDR50LT) using methods of automatic generalisation” in 2013; “Automatization of spatial data generalisation and preparation of (geo) reference spatial data set of the Republic of Lithuania at scale 1:50.000 (GDR50LT)” in 2014 and “Preparation of topographic map of Republic of Lithuania at scale 1:50.000 (TOP50LKS, TOP50LKS-SR)” in 2015–2016. The development and enhancement of the base map for *Geoportal.lt* was a continuous process and information collected 2010–2016 was used.

The outcomes

The discovered differences between 1:50 000 scale maps compiled using ADG and ACG methods from the 1:10 000 scale GDR10LT dataset are summarized in Table 3.

Table 3. Generalization methods used for design of TOP50LKS map and for GBM 1:50 000 scale layers

Characteristics	ADG	ACG
Geometric accuracy of cartographic representation	Geometry of mapped objects is generalized	Original object geometry is preserved; representation may distort geometry to some extent due to visual merge of the symbols
Representation of characteristics of map features	More capabilities due to possibility to generalize geometry	Limited capabilities
New feature classes	Present	Not present
Volume of change of cartographic representation and (or) its characteristics	Larger; requires changes of generalization strategy, generalization model parameters, and of the system of conventional signs	Smaller; changes are simply made by selection by attributes and by the change of conventional signs
Level of generalization of cartographic representation	Higher	Lower
Risk of errors in cartographic representation	Possible inaccuracies due to various transformations of the source data; errors due to technical problems that may occur during processing data by the automatic models.	Excessive generalization due to merging of graphic elements
Involved team	2 cartographers, 5 model developers, 1 programmers	1 cartographer and 1 web-services administrator

It must be noted that some of the above listed differences are related with the primary purpose of the map: map designed for printing (ADG method) and map for interactive use that contains different scale layers (CDG method).

Difference in maps created by using both methods is reflected in the map samples:

1. Total level of generalization is higher when ADG method is used. CDG method yields more complex map and requires additional design including employment of colour characteristics (hue, saturation and value) to represent object hierarchies and relationships, (Fig. 2).

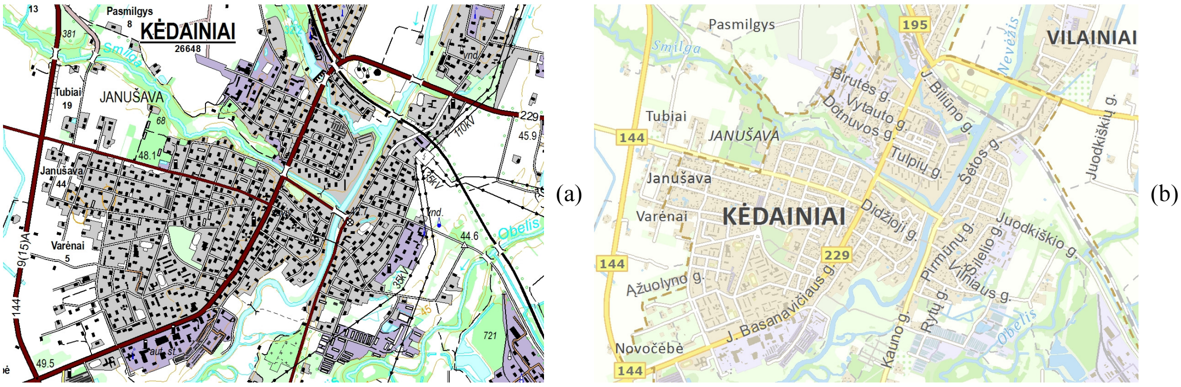

Fig. 2. Fragment of 1:50 000 scale maps designed using ADG (a) and CDG (b) methods: general view

2. Adoption of the ADG method employs all known generalization methods. CDG method allows only limited set of methods, namely attribute generalization. Geometric generalization is replaced in CDG method by specific representations. For example, (Fig. 3) with ADG method buildings are reclassified and represented by different symbols (a) whereas CDG method preserves same geometry but due to representation objects may be made visually inseparable or invisible (b);

3.

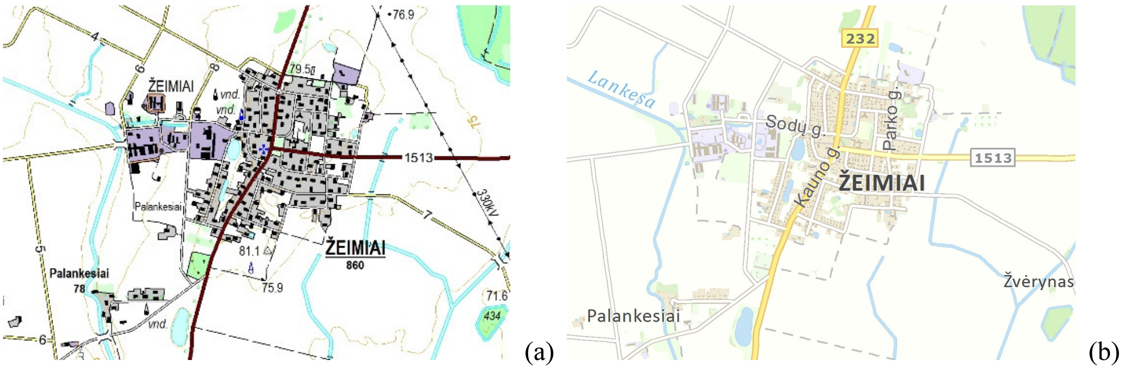

Fig. 3. Fragments of 1:50 000 scale maps: generalization of buildings in ADG (a) and CDG (b) maps

4. Overlap of objects causes more problems in CDG maps, because geometry is not modified. In the most of cases they can be resolved by appropriate choice of visual variables (colour, texture) as shown in Figure 4.

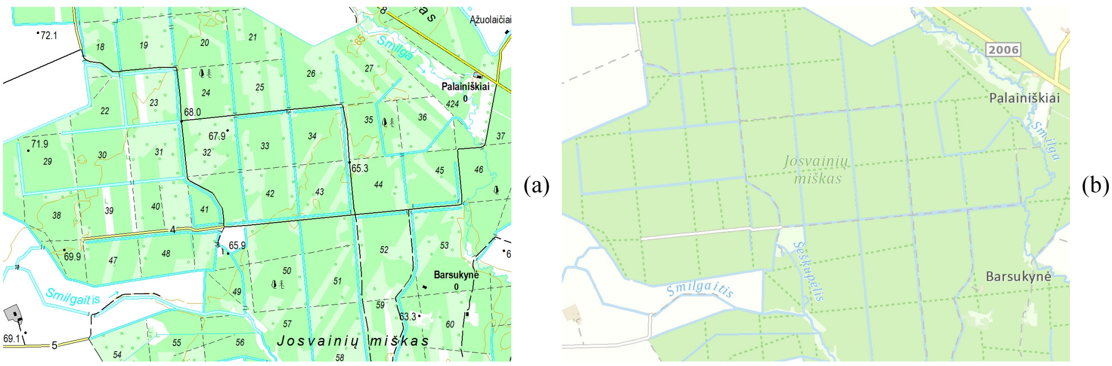

Fig. 4. Fragments of 1:50 000 scale maps: overlap of roads and hydrography in ADG (a) and CDG maps (b)

Conclusion

Adoption of the ADG method employs all known generalization methods. CDG method allows only attribute transformation (qualitative and quantitative census) whereas geometric methods are implemented by means of symbols.

In general, fully automated data generalization (ADG method) has a potential to produce better cartographic representation as object characteristics and relationships are concerned.

However, a multi-scale map generated by means of cartographic generalization (CDG method) can for many applications successfully replace multi-scale map generated from separately generalized data sources. This method allows faster and cheaper production of map at the same scale. Besides that, a multi-scale map allows for flexible balancing of map information load thus more information can be represented.

Interactive multi-scale map is preferred by users of web map services in the Internet and mobile applications. The research has demonstrated that such maps can achieve sufficient cartographic communication quality.

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Disclosure statement

The authors declare that they do not have any competing financial, professional, or personal interests from other parties.

References

Beard, M. K.; Mackaness, W. 1991. Generalization operators and supporting structures, in *Proceedings Auto-Carto* 10: 29–45.

Berliant, A. M. 2003. *Kartovedenie*. Moskow: Aspekt Press. 477 p.

Bader, M.; Barrault, M.; Regnauld, N.; Musriere, S.; Duchene, C.; Ruas, A.; Fritshck, E.; Lecordix, F.; Barillot, X. 1999. *AGENT Workpackage D2 – Selection of Basic Algorithms*. Technical report, Departament of Geography, University of Zurich.

Cecconi, A. 2003. *Integration of cartographic generalization and multi-scale databases for enhanced web mapping:* PhD thesis. Department of Geography, University of Zurich.

Lamy, S.; Ruas, A.; Demazeau, Y.; Jackson, M.; Mackaness, W.; Weibel, R. 1999. The Application of Agents in Automated Map Generalization, in *the 19th ICA/ACI International Cartographic Conference,* 14–21 August 1999, Ottawa, Canada.

Lithuanian Spatial Information Portal [online]. 2017 [cited 22 August 2017]. Available from Internet: www.geoportal.lt

McMaster, R. B.; Shea, K. S. 1992. *Generalization in digital cartography*. Association of American Geographers. 134 p.

Papšienė, L. 2014. *The improvement of modelling and harmonisation of spatial information in digital cartography:* PhD thesis. Department of Geodesy and Cartography, Vilnius Gediminas technical university.

Papšienė, L.; Budrevičius, J. D.; Marma, M. 2014. The automated update of cartographic data at a scale of 1:50,000 in Lithuania: problems and solutions, in *9th International Conference "Enviromental engineering"*, 22–23 May 2014, Vilnius, Lithuania.

Roth, R. E.; Brewer, C. A.; Stryker, M. S. 2011. A typology of operators for maintaining legible map designs at multiple scales, *Cartographic Perspectives* 68: 29–64. https://doi.org/10.14714/CP68.7

Ruas, A.; Lagrange, J. P. 1995. Data and knowledge modelling for generalisation, GIS and Generalization, Methodology and Practice, *GISDATA* 1: 73–90.