Assisted cartographic generalization: Can we learn from classical maps?

Vaclav Talhofer*, Libuse Sokolova**

*University of Defence, Department of Military Geography and Meteorology, Brno, the Czech Republic, E-Mail vaclav.talhofer@unob.cz
*Military Geographic and Hydrometeorological Office, Dobruska, the Czech Republic, E-Mail libuse.sokolova@vghur.army.cz

Abstract. Cartographic generalization is a complex process in which the holistic approach is necessary to apply. Cartographic tools that are usually part of production systems are very effective means for map production. The article deals with comparison between classical and present approaches to the cartographic generalization. The parameters for recent tools are found in the classical topographic maps of scales of 25K, 50K, and 100K. The goal of the task is to find out which parameters of given tools are essential to enable to receive the results corresponding as much as possible to the original map. Two different types of landscape were chosen as an example – an urban area and rural one.

Keywords: generalization, GIS, automated generalization, topographic maps

1. Motivation

The cartographic generalization of topographic maps content is very complicated processes in which the given rules are necessary to follow but the previous experiences of map editor influence the final results as well. The map editor was able to solve the map content as a holistic problem in the classical technologies and then could apply the generalization rules for given objects in accordance with surrounding situation.

The digital technologies are characterised by a large number of tools which facilitates working with features or group of features. But the whole map content harmonization can be done subsequently. It is also necessary to determine the basic parameters of used tools. It is a question whether is possible to derive appropriate parameters from the old maps studying.

The present web mapping services usually change the maps according to the view scale abruptly. The development of communication and information technology probably allows changing maps scale continuously including on-line generalization. Tools for generalization are ready to help for solution of particular or complex tasks; however, the question is what parameters should be automatically set to maintain the character of landscape.

The simple research was conducted at the Department of Military Geography and Meteorology of the University of Defence to try to find mentioned parameters from old topographical maps. Two types of typical landscape were chosen for this research, which are mostly occurring in the Czech Republic – built-up and rural area. Topographical maps issued in fifties and seventies in the last century were compared with the present topographical maps. The initial scale was 25K and their generalization into 50K and 100K scales was studied using tools of ArcGIS system.

2. State of Art

Generalization is a never-ending phenomenon of cartography. Many publications describing the cartographic generalization were issued in the last century and in the beginning of present century. The earlier publications were dealing mainly how to use rules in manually processes e.g. (Töpfer, 1974; Srnka, 1968; Saliscev, 1976). The answers like how many objects should be selected for smaller scale, what parameters of census can be set for given scale etc. can be found in these publications. There are many examples of generalization´s manners from which cartographers could learn. The theories were implied in editorial guidelines, but their final application for given landscape was only a question of specific map editor.

The development of a computer technology enabled also a development of a computer graphic and later on methods of the cartographic visualization and a map content harmonisation. The first objective methods were summarised in several publications in the beginning of the nineties of last century (Clayton, 1985; Buttenfield & McMaster, 1991), or in textbooks (Robinson, Morrison, Muhercke, Kimerling, & Guptil, 1995; Slocum, McMaster, Kessler, & Howard, 2005), etc. Present publications are mainly focussed on different algorithms description or utilization of these algorithms as tools (Burghardt, 2005; Haowen & Robert, 2008; Neun, 2007; Lee & Hardy, 2005; ESRI, 2013, Stanek 2010). Haw the generalization works in a map content published e.g. (MacEachren, 2004; Svatonova, 2010).

3. Goals

The military mapping of the Czech Republic territory has a long history beginning at the of Austria-Hungary monarchy. Very experienced cartographers with the field practices of topographic mapping usually edited the content of smaller scale maps. Their field experience helped them also at a process of generalization. All military topographic maps created by classical technology were evaluated as very good quality products.

The Military Geographic Service used to exploit the classical technology until nineties of the last century. By this time, the transition to computer-assisted methods based on the ArcGIS system was started. ArcGIS contains many useful tools including generalization tools which are used for present topographic maps content generalization (ESRI, 2013). Unlike previous manual methods of generalization tools are applied separately for given parts of objects and the final content is completed using harmonization of these separate parts. The similar situation is if the sources for web mapping services (WMS) are necessary to prepare.

But the question remains, what specific tools are useful for the given type of landscape and what parameters it is appropriate to set up in these tools to compile the topographic maps content and also for automatic generalization in WMS. While there is the possibility of using the previous experiences of former cartographers to verify what the current tools would achieve the same result, as the manual generalization. The aim of our study was to determine whether the procedure is possible and real.

4. Methods

For the analysis of practices have been chosen selected topographic maps in the scales of 1:25K, 50K and 100K, issued by the Ministry of Defence from 1954 to 1990, which were mostly done with the manual generalization. In addition, previous maps were compared with the current edition of these maps, which are wholly generated in ArcGIS. Specifically, the following map editions were analysed:

- topographic maps of S-1952 geodetic datum (Krasovsky spheroid, Gauss Projection) issued from 1954 to 1957;
- topographic maps of S-1942 geodetic datum (Krasovsky spheroid, Gauss Projection) issued from 1975 to 2005;
- topographic maps of WGS84 geodetic datum (WGS84 spheroid, UTM Projection) issued since 2005;

Two regions were selected for research purposes; one from built-up area (Brno and surroundings) and the one from the rural landscape (around Kojetín). The contents of the selected maps sheets of all scales in the S-1942 and S-1952 systems were necessary first to digitize. Then suitable tools for generalization and their parameters were searched for in order to achieve a similar generalization as a manual procedure. If such parameters were found, they were subsequently compared with the parameters of the current technology used in the editing of topographic maps in the Military Geographic and Hydrometeorological Office of the Army of the Czech Republic (Sokolova, 2012).

The main results are described in the following text.

4.1. Generalization of topographic maps of S-1952

Editorial guidelines for generalization were established only as a recommendation and it was within the consideration of a given cartographer, how it applied to the specific situation. As a result of this condition cartographers often completely changed the shape of the objects, which current tools do not allow.

The selection and aggregation were primarily used for built-up areas generalization. In general it can be said that buildings in the urban area were preserve in their form much more faithfully than building in the rural area, where the expression of the character of the buildings was very simplified and sometimes completely changed their form. Used generalization procedures generally did not correspond to the current, and therefore it was not possible to find appropriate tools that would be applicable to a larger number of areas.

The paradox is "the opposite of generalization", in which on a map of a smaller scale, where some buildings are drawn more detailed than in the original map. This paradox, however, resulted from the conditions at the time of creating maps and given strict deadline of their issue (sees **Figure 1**, which shows the buildings layer scale 1: 50 000 scale map on a 1: 25, 000).

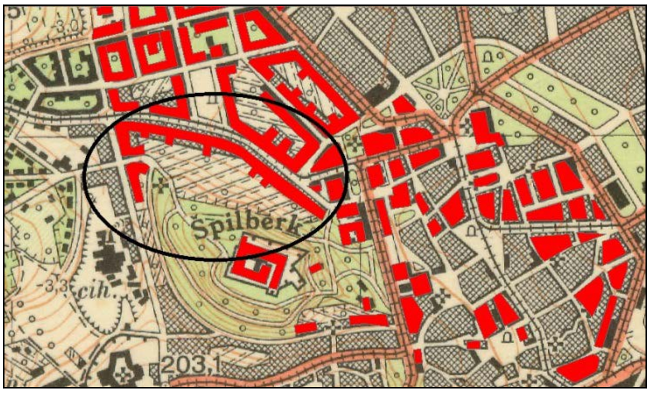

Figure 1. The layer of buildings in scale of 50K onto source map of 25K scale

The generalization of a transport network is mostly affected by a selection and displacement. A relatively large number of forest and field cart tracks were eliminated in rural areas. The complex transport system was maintained much more in urbanized areas, only some short roads were eliminated.

Simplification and smoothing lines were applied as basic generalization methods of hydrology. Some small water areas were selected, but no rules were found for given census. The main point of view was a readability of the map. Preserved water surfaces have deformed shapes, or were shifted.

If we try to find suitable tools in *ArcGIS*, the best was *Smooth line*, in which the *PAEK* algorithm with a tolerance of 90 m for the generalization to scale of 50K and 120 m for 100K scale was the best. The result of the generalization from 25K to 50K can be seen in **Figure 2**, where the generalized layer using *ArcGIS* tool is displayed in black. The result of the generalization to the map of 100K is in **Figure 3**.

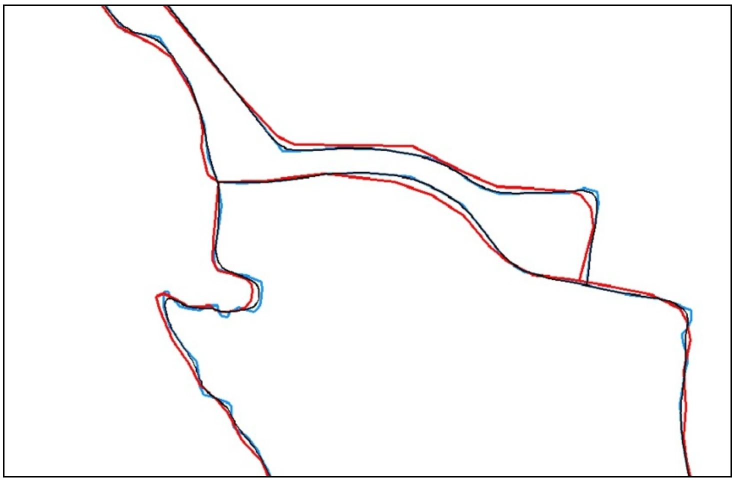

Figure 2. The application of Smooth Line tool, tolerance of 90 m, (blue - original 25K, red 50K, black – PEAK, tolerance of 50 m)

Figure 3. The application of Smooth Line tool, tolerance of 250 m – (original 50K – red, digitised line in 100K scale – green, smooth line tools – black)

Summary of the changes and their numerical expression are listed in the following tables. Line features are expressed as the sum of all lengths of individual features, similarly aerial features as the sum of all areas of individual features. The result is a ratio (in percentage), which indicates how much of the layers remain regardless of the generalization. It can be said that the liner layers (transport and water network) this figure reflects the percentage of derived layers, in which it was a generalization.

To express the common part of original and generalized features the intersection of corresponding layers was calculated and then their ratio (in percentage). The calculated values are given in tables **Table 1** and **Table 2** for the rural and urban landscape type.

Map sheets Kojetín S-1952	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	106474	410567	397466	429163	1536457
1:50 000	105327	380189	265318	526505	1122072
1:100 000	100329	365522	160369	1301108	0
1:25 000 ⟶ 1:50 000					
Intersection	0	313284	0	127608	852816
Ratio of sum of lengths or areas	99%	93%	67%	123%	73%
Match	0%	82%	0%	24%	76%
1:50 000 ⟶ 1:100 000					
Intersection	0	287676	0	187994	-
Ratio of sum of lengths or areas	95%	98%	61%	247%	0%
Match	0%	79%	0%	14%	-

Table 1. Changes at the area of Kojetín, the system of S-1952

Map sheets Brno S-1952	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	13166	1279413	38634	438271	544901
1:50 000	13156	1277190	34785	624536	227470
1:100 000	13030	1261454	29451	958836	0
1:25 000 ⟶ 1:50 000					
Intersection	0	1205702	0	233026	197677
Ratio of sum of lengths or areas	100%	100%	90%	142%	42%
Match	0%	94%	0%	37%	87%
1:50 000 ⟶ 1:100 000					
Intersection	0	1198538	0	372020	-

Ratio of sum of lengths or areas	99%	99%	85%	154%	0%
Match	0%	95%	0%	39%	-

Table 2. Changes at the area of Brno, the system of S-1952

It is evident from the tables that water flows and areas were generalized very few.

Similarly it can be said about the roads and streets in built-up area where only minimum of small parts of transportation network was eliminated in smaller map scale. The other situation was in rural area where many field and forest cart tracks disappeared in smaller scales. Chosen buildings in derived maps were usually driven larger than in original maps due to their readability. Therefore ratio of the sum of their areas is more than 100% in both generalized map sheets – rural and built-up landscape.

Particular results to generalization of the maps in S-1952

Whereas that generalization of the topographic maps of the system S-1952 was strongly influenced by individual approach to specific cartographers, it can not be obtained any appropriate parameters for present generalization's tools from these maps.

4.2. Generalization of topographic maps of S-1942

The rules for generalization of topographic maps of the system S-1942 were based on theory published e.g. in (Srnka, 1968; Töpfer, 1974). Nevertheless their interpretation remained strongly influenced by personal attitude of given cartographers, because only parameters of generalization based on these theories were written in editorial guidelines, but own drawing was done manually.

Separate buildings and block of buildings were again generalized differently in different territories. In the city centres many buildings were aggregated in blocks and simplified. Blocks borders were often displaced to release place for a street´s symbol. Vice versa, in the rural landscape a much smaller selection of buildings was made, and most of the buildings were not generalized, but they were often displaced and enlarged. Therefore no appropriate general tools could be found.

Transport network was generalized mainly using selection and displacement methods and its geometry was simplified. The whole generalization was similar to the topographic maps of S-1952 edition.

Hydrological network was partly shifted, but its main shapes were reminded. Only small waves of water lines were generalized. When appropriate tools were found, the best match was the *Smooth line* method with tolerance of 70 m for the scale of 50K and 100 m for 100K. Result can be seen in **Figure 4**.

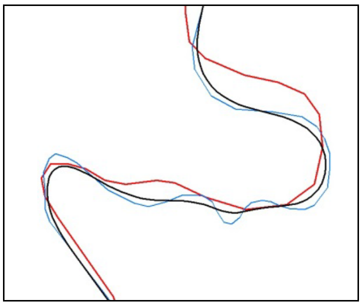

Figure 4. Smooth Line tool application with the tolerance of 70 m – blue - original map 25K, red - digitized line of map 50K, black - tool application.

Summary of results are in the following tables.

Map sheets Kojetín S-1942	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	102998	1738608	294390	966259	1848222
1:50 000	101687	1684250	249665	1352145	1804008
1:100 000	100860	1730506	145010	1743945	0
1:25 000 ⟶ 1:50 000					
Intersection	0	1609317	0	481272	1377095
Ratio of sum of lengths or areas	99%	97%	85%	140%	98%
Match	0%	96%	0%	36%	76%
1:50 000 ⟶ 1:100 000					
Intersection	0	1552687	0	547482	-
Ratio of sum of lengths or areas	99%	98%	58%	129%	0%
Match	0%	90%	0%	31%	-

Table 3. Changes at the area of Kojetín, the system of S-1942

Map sheets Brno S-1942	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	13094	1354850	36563	854442	1295468
1:50 000	13021	1373222	30901	182950	1171990
1:100 000	12723	1371742	23838	92129	1331295
1:25 000 ⟶ 1:50 000					
Intersection	0	1332267	0	65370	795672
Ratio of sum of lengths or areas	99%	101%	85%	21%	91%
Match	0%	97%	0%	36%	68%
1:50 000 ⟶ 1:100 000					
Intersection	0	1366908	0	27781	852413
Ratio of sum of lengths or areas	98%	99%	77%	50%	114%
Match	0%	99%	0%	30%	64%

Table 4. Changes at the area of Brno, the system of S-1942

It is evident from the table that hydrological network was generalized as well as in the maps of the S-1952 system. Water areas cover approximately the same in all scales. Almost a seventh of the transport network has been removed in the scale of 50K, subsequent it has been removed in the scale of 100K. Separate buildings were much more aggregated into blocks of buildings in build-up landscape while most of separate buildings remained as separated in smaller scales in rural landscape.

Particular results to generalization of the maps in S-1942

It is evident from that results that in the approach to generalization was similar to the previous map edition. Despite the fact that the parameters of the generalizations were derived on the basis of the theoretical principles referred to in (Srnka, 1968; Töpfer, 1974) there still remains a strong individual approach. Therefore similarly to the previous maps edition, it can not be obtained any appropriate parameters.

4.3. Generalization of topographic maps of UTM/WGS84

Maps in WGS84 coordinate system have already been edited by using computer-assisted tools generalizations, which were included with various versions of ARC/INFO, or ArcGIS. These tools have primarily been used for generalization of individual groups and for identification of graphics and topological conflicts during data editing and cartographic harmonization. Initial parameters of the generalizations, which are applied for different tools, are based on the editorial guidelines of given map scale (MOCR, 2008). Because tools implied in ArcGIS apply the present theories of cartographic generalization, the result of map content is significantly improved in the geometry of the generalized object and also in the objectification of the whole process.

The generalization of built-up areas is the most commonly applied method of selection, as well as methods of generalizations of shapes of buildings and their aggregation into blocks. However, the selection is not effected by any general tools and it is up to the specific cartographer which buildings will be eliminated.

The shape of transport network is generalized mainly by the Douglas-Paucker algorithm. Only the least significant streets are eliminated in built-up areas and the least significant forests and field carts tracks in the rural landscape.

Also water lines and water areas are generalized only few. Their shapes, lengths, and areas are nearly the same in all scales. Only the smallest streams and ponds are eliminated in the scale of 100K, and same water lines are displaced during cartographic harmonization due to their conflict with roads.

Summary of results are in the following tables.

Map sheets Kojetín WGS84	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	99536	1869164	335089	1121917	1840450
1:50 000	99536	1869164	327295	551660	1665182
1:100 000	98066	1720154	175615	508261	2426836
1:25 000 ⟶ 1:50 000					
Intersection	99536	1869164	309254	420276	1529894
Ratio of sum of lengths	100%	100%	98%	49%	90%

or areas					
Match	100%	100%	94%	76%	92%
1:50 000 ⟶ 1:100 000					
Intersection	94949	1655509	168418	152193	1188144
Ratio of sum of lengths or areas	99%	92%	54%	92%	146%
Match	97%	96%	96%	30%	49%

Table 5. Changes at the area of Kojetíno, the system of WGS84

Map sheets Brno WGS84	Water flows [m]	Water areas [m^2]	Roads and streets [m]	Buildings [m^2]	Blocks of buildings [m^2]
1:25 000	13067	1361887	42489	810018	1196179
1:50 000	13064	1360658	39512	156957	1146001
1:100 000	13067	1377114	25755	45813	1156370
1:25 000 ⟶ 1:50 000					
Intersection	12630	1355039	36086	120459	1047807
Ratio of sum of lengths or areas	100%	100%	93%	19%	96%
Match	97%	99%	91%	77%	91%
1:50 000 ⟶ 1:100 000					
Intersection	5493	1360658	15738	13432	858438
Ratio of sum of lengths or areas	100%	101%	65%	29%	101%
Match	42%	99%	61%	29%	74%

Table 6. Changes at the area of Brno, the system of WGS84

The results proved that only small changes appeared after generalization from 25K to 50K scale. The biggest changes were caused by the aggregation of separate buildings into blocks in the city centres. Approximately one third of communications were eliminated in the scale of 100K, mainly field and forest carts in the rural landscape.

4.4. Results comparison

The following table enables the final comparison of particular results described in the previous text. The values in this table are calculated by:

$$x = \frac{m.100 - y}{m} ,$$

where x is the value of maintaining of all original layers;

$y = y_1 + y_2 + ... + y_m$ = sum of the deviations of each layer of 100%

m = number of used layers

Comparison of total values		Map sheets of S-1952		Map sheets of S-1942		Map sheets of WGS84	
		Kojetín	Brno	Kojetín	Brno	Kojetín	Brno
1:50 000	Total area	82%	78%	88%	79%	87%	82%
	Match	36%	44%	42%	40%	92%	91%
1:100 000	Total area	41%	66%	65%	82%	78%	78%
	Match	23%	34%	30%	39%	74%	61%

Table 7. Results comparison

It is evident from the table that more objects are preserved in the later map editions and their shape and other characteristics correspond to their original forms. The great leap is mainly in conformity with the original layers on the last maps in the system WGS84.

5. Conclusion

The generalization is one of the main processes of cartography and its quality is always increasing with the geoinformation systems development.

The generalization of the map content in maps when manual technologies were utilized was heavily influenced by the subjective approach. Although cartographers were able to harmonize the whole map content during its editing, no objective algorithms were used and the generalization rules were used only as instructions. The final results depended on experience and fillings of the specific cartographer. Therefore it was not possible to find any appropriate parameters of present tools for generalization. On the other hand it was proved that substantial differences between urban and rural landscape generalization are mainly for transport network and built-up areas in all editions which could be used as a characteristics for such a type of landscape.

The main advantage of the computer-assisted generalization is an objective approach and consistent procedures that address each layer separately. Thanks to the tools generalized layers are more faithful to their original layer. As one of the most important facts is positional conservation of hydrological network that best characterizes the surrounding relief.

Very useful tools are the tools for graphic conflicts solution, which enable cartographers to perform a partial harmonization and thereby avoid interpretative errors.

Acknowledgement

The work presented in this paper was supported within the project for development of Military geography and meteorology supported by the Ministry of Defence of the Czech Republic and the project NeoCartoLink founded by Ministry of Education of the Czech republic.

References

Burghardt, D. (2005). Controlled Line Smoothing by Snakes. *GeoInformatica* , *9*(3), pp. 237-252.

Buttenfield, B. P., & McMaster, R. B. (1991). *Map generalization: Making rules for knowledge representation* (Longman Scientific & Technical ed.). Essex: Longman.

Clayton, V. H. (1985). *Cartographic generalization: A review of feature simplification and systematic point elemination algorithms* (NOAA technical report NOS 112 ed.). Rockville, USA: National Charting Research and Development Laboratory.

ESRI. (2013). User documentation. Copyright © 1995–2013 Esri.

Haowen, Y., & Robert, W. (2008, 8). An algorithm for point cluster generalization based on the Voronoi diagram. *Computers & Geosciences*, *34*(8), pp. 939-954.

Lee, D., & Hardy, P. (2005). Automatig generalization - tools and models. *XXII International Cartographic Conference (ICC2005).* A Coruña: The International Cartographic Association (ICA-ACI).

MacEachren, A. M. (2004). *How Maps Works: Representation, Visualization and Design*. New York, USA: The Guilford Press.

MOCR. (2008). *Topo-4-5: Map symbols of topographic maps scales 1:25000, 1:50000, and 1:100000. (in Czech)* Praha. Ministry of Defence of the Czech Republic.

Neun, M. (2007). *Data Enrichment for Adaptive Map Generalization Using Web Services* (PhD Thesis ed.). Zurich: Universitat Zurich.

Robinson, A. H., Morrison, J. L., Muhercke, P. V., Kimerling, A. J., & Guptil, S. C. (1995). *Elements of Cartography* (6 ed.). New York, USA: John Wiley & Sons.

Saliscev, K. A. (1976). *Cartographic production (Kartovedenije).* Moscow: Moscow University Publishing.

Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2005). *Thematic Cartography and Geographic Visualization* (2 ed.). Upper Saddle River, NJ 07458: Pearson Education, Inc.

Sokolova, L. (2012). *The analysis of generalization schemes of topographic maps, in Czech.* Diploma thesis ed. Brno: University of Defence, Faculty of Military Technologies, Department of Military Geography and Meteorology.

Srnka, E. (1968). *Analitical solution in the cartographic generalization*. (in Czech). Habilitation theses ed. Brno. Military Academy in Brno.

Stanek, K., Friedmannova, L, Kubicek, P. et al. (2010). *Selected issues of cartographic communication optimization for emergency cetres. International journal of digital earth, Volume: 3 Issue: 4 Special Issue: SI, pp. 316-339*

Svatonova, H. et all. (2010). Role and representation of geographic information within crisis management. *In International conference on military technologies.* Trenčín: Alexand Dubcek University of Trencin, pp. 717-726. ISBN 978-80-8075-453-2.

Töpfer, F. (1974). *Kartographische Generalisierung.* Leipzig: VEB Hermann Haack.