Extended Abstract zu Dagstuhl Konferenz April 14-17, 2009
Svn 1675
Worte 1.417

Why Is Cartographic Generalization So Hard?

Andrew U. Frank
Department for Geoinformation and Cartography
Gusshausstrasse 27-29/E-127-1
A-1040 Vienna, Austria
frank@geoinfo.tuwien.ac.at

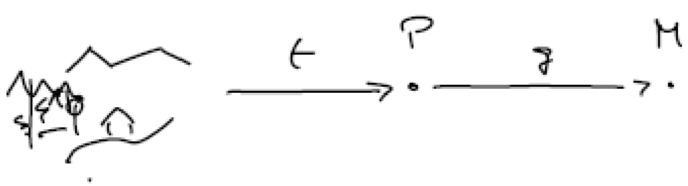
1 Introduction

I remember first presentations about cartographic generalizations (Spiess 1971), where tools for generalization were shown, but the conclusions stated, more or less clearly, that fully automated cartographic generalization was not possible. There has been an impressive stream of research documenting methods to generalize maps. The consensus today seems to be that automated tools under control of a cartographer are the most effective means (Buttenfield et al. 1991; Weibel 1995).

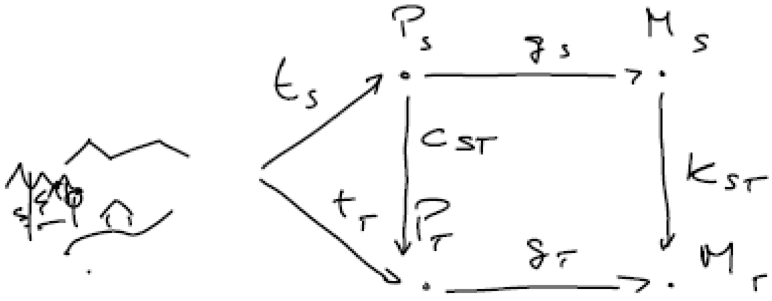
In this contribution some fundamental aspects of map making, including generalizations are analyzed. Map generalization is studied by most map producers, especially the National Mapping Agencies, because they have to maintain maps at different scale and it appears economical to derive a map at smaller from a map of a larger scale by an automated process. Equally important is the production of maps at arbitrary scales for the illustration of web pages. These tasks are the backdrop for the following abstract analysis.

2 Cartographic Generalization Is AI-Hard

A naïve view is that a map at a scale *s* is made from areal photographs or remote sensing image of a corresponding scale.



The map *M* is the result of a process *g* (for granularization, meaning identification and delimitation of objects), which starts from a photograph produced by process *t* (for taking pictures). Consider two maps a scale *S* and *T* $(S > T)$ can be produced independently by processes $g_S \cdot t_S$ and $g_T \cdot t_T$.



Photographs of smaller scale may be produced from larger scale photographs by the filtering operation c_{ST} thus M_T can be produced without taking the photograph at scale T

$$g_T \cdot c_{ST} \cdot t_S = g_T \cdot t_T.$$

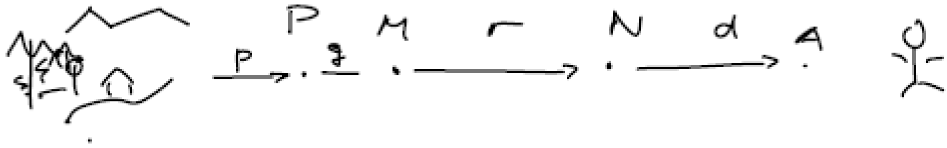
The desired automatic generalization k_{ST} producing map M_T from maps M_S shows the equivalence of

$$k_{ST} \cdot g_S = g_T \cdot c_{ST}.$$

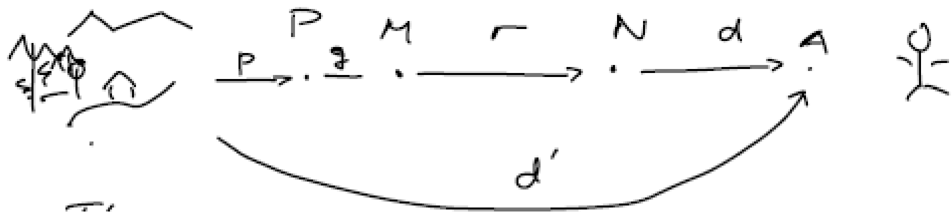
Unfortunately, this is not realistic and a function k_{ST} has not been found, as little as an inverse of g_S is possible. The production of a map from a photograph or generalization requires human common-sense understanding of the world. It is equally difficult as recognition of pictures, understanding natural language text, etc. This is to say that meaning it is as hard as any other artificial intelligence task. In allusion to the “NP-hard” qualification of computer algorithms, this is sometimes called “AI-hard”. The human common sense is required when an operation in cartography requires an interpretation of the context. For example, if a rule calls for a certain generalization algorithm in urban and for another in rural context. Then a complex set of properties and prior knowledge of usual world circumstances is required to decide where the buildings are urban and where rural and thus on the applications of these rules. The process can be automated if the decision is based on directly observable facts without interpretation (e.g., density of buildings). A formalization of human common sense is attempted but not yet succeeded (CYC 2000)

3 Maps to Inform Users

Reconsidering the question of generalization, but including the map user yields a somewhat different view. A user reads a map because he needs some information to make a decision *D*. It is appropriate to differentiate between models of the world (at scales) and cartographic models. The user expects to find the information required in the map.



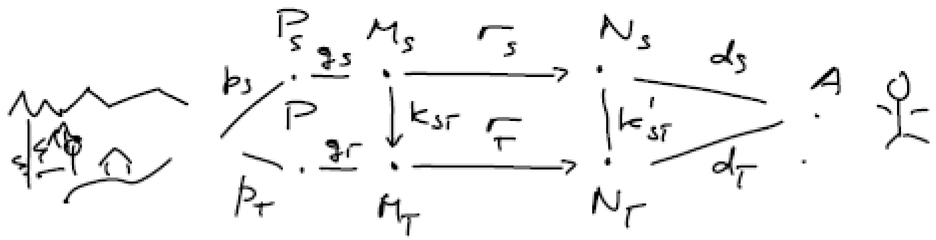
The user makes the decision *d* leading to action *A* from a cartographic model that is derived from the world model by a rendering process *r*. The information the user receives is considered correct, if the decision she makes is the same as if she would have made the same decision directly observing the world:



The equation

$d' = d \cdot r \cdot g \cdot p$

means that the facts relevant for the decisions are preserved through the mappings *p*, *g*, *r*, and *d*. The same applies when considering using two maps at different scale:



The cartographic model generalizations k_{ST} or the cartographic generalization k'_{ST} must preserve the relevant facts such that

$d_T \cdot r_T \cdot k_{ST} = d_S \cdot r_S$
or
$d_T \cdot k'_{ST} = d_S$.

This is, for specific decisions, likely automatable, because it does not imply $v_T \cdot k_{ST} = k'_{ST} \cdot v_S$, but only that the relevant facts are preserved by k_{ST}. If we concentrate on a specific decision for which it is known which facts are relevant (Achatschitz 2008).

4 Conclusion

4.1

Maps must contain the information necessary for a task. Pretending to produce general purpose maps—meaning maps useful for a wide variety of purposes—is requiring human interpretation of the real world and an expectation of probable uses of the map. The production of general purpose maps is not likely fully automatable. But there are also no guarantees that a multipurpose map will be useful for a specific task, probably with the exception of navigation with a means of transportation commensurate with the map scale, because this is the task most likely considered when making the map.

4.2

To understand what the user decides and what information is relevant for the decision (Achatschitz 2008), is influencing the generalization, because the generalization process must leave the corresponding facts invariant; the decision must be the same independent one of generalization.

4.3

Spatial facts need context to make them understandable. Some of this context is not optional but crucial for the user to make the decisions correctly. For example, using a map for navigation is only possible if landmarks and general situation around my route is visible. Optional context, not contributing to the decision, should be avoided, because it is noise, disturbing the map reader. Adding irrelevant context as much as space permits in case the map is used for another decision is not justified, because the absence of things shown is information that may influence a decision as well. All facts of a certain type must be shown and a selective representation "as space permits" is misleading.

4.4

Making different map for different tasks is possible with today's technology, if it can be fully automated. Giving up the goal of a general purpose map and make only specific maps seems to avoid the need for human judgment. If the map serves for decision *d* then all facts relevant for *d* must be shown.

Note that planning, describing and driving from *A* to *B* are three different sets of decisions (Timpf et al. 1992) and as a consequence requires different maps. Similarly, a map for exploring a foreign city, a map for a hike in Austria and a map for driving are at different scales (likely 1:10.000, 1:50.000, 1:300,000). The speed of movement on the map varies much less than the speed of the modes of transformation, namely only between 10 and 20 cm/hour.

4.5

The classes of facts relevant for a decision have a footprint of a certain size in space (and time, but this is ignored here); we can assign a size to a decision. This gives a *decision @ scale* counterpart to the *concept @ scale* introduced by Kuhn (1994). These two ideas are connected: the scale of a decision and the scale of the object must correspond. This is the consideration used for selecting the right map scale for a task! The conceptualization to use for the facts relevant for the decision must be corresponding. For example, the concept of building in a map for inner city navigation should in scale included small kiosks as buildings; even when the usual definition of building for other purposes requires a 60 sqm footprint (Riedl 2009). Note that on maps for car navigation between cities buildings are not shown (only landmarks).

4.6

I suggest that we give up the chimera of the general purpose map—which was mostly a navigation map at the scale anyhow—and concentrate research on mapping for particular decisions.

References

Achatschitz, C. (2008). Preference-Based Visual Interaction Spatial Decision Support in Tourist Information Systems. Vienna, Technical University Vienna. Doctor.
Buttenfield, B. and R. McMaster, Eds. (1991). Rule based cartographic generalization. London, Longman.
CYC. (2000). "The CYC Corporation Web Page." Retrieved 21 November, 2000, from http://www.cyc.com/tech.html.
Kuhn, W. (1994). Defining Semantics for Spatial Data Transfers. 6th International Symposium on Spatial Data Handling, Edinburgh, UK, IGU.
Riedl, M. (2009). Erstellung von Baulandbilanzen in Tirol. 15. Internationale Geodätische Woche Obergurgl, Ötztal Tirol, Wichmann.
Spiess, E. (1971). The Need for Efficient Base Maps in Thematic Mapping. 5th International Conference on Cartography, Stressa, Italy, Kartographisches Institut der ETH.
Timpf, S., G. S. Volta, D. W. Pollock and M. J. Egenhofer (1992). A Conceptual Model of Wayfinding Using Multiple Levels of Abstractions. Theories and Methods of Spatio-Temporal Reasoning in Geographic Space. A. U. Frank, I. Campari and U. Formentini. Heidelberg-Berlin, Springer Verlag. 639: 348-367.
Weibel, R. (1995). "Map generalization in the context of digital systems." CaGIS 22(4): 259-263.