EuroSDR research on state-of-the-art of automated generalisation in commercial software: main findings and conclusions

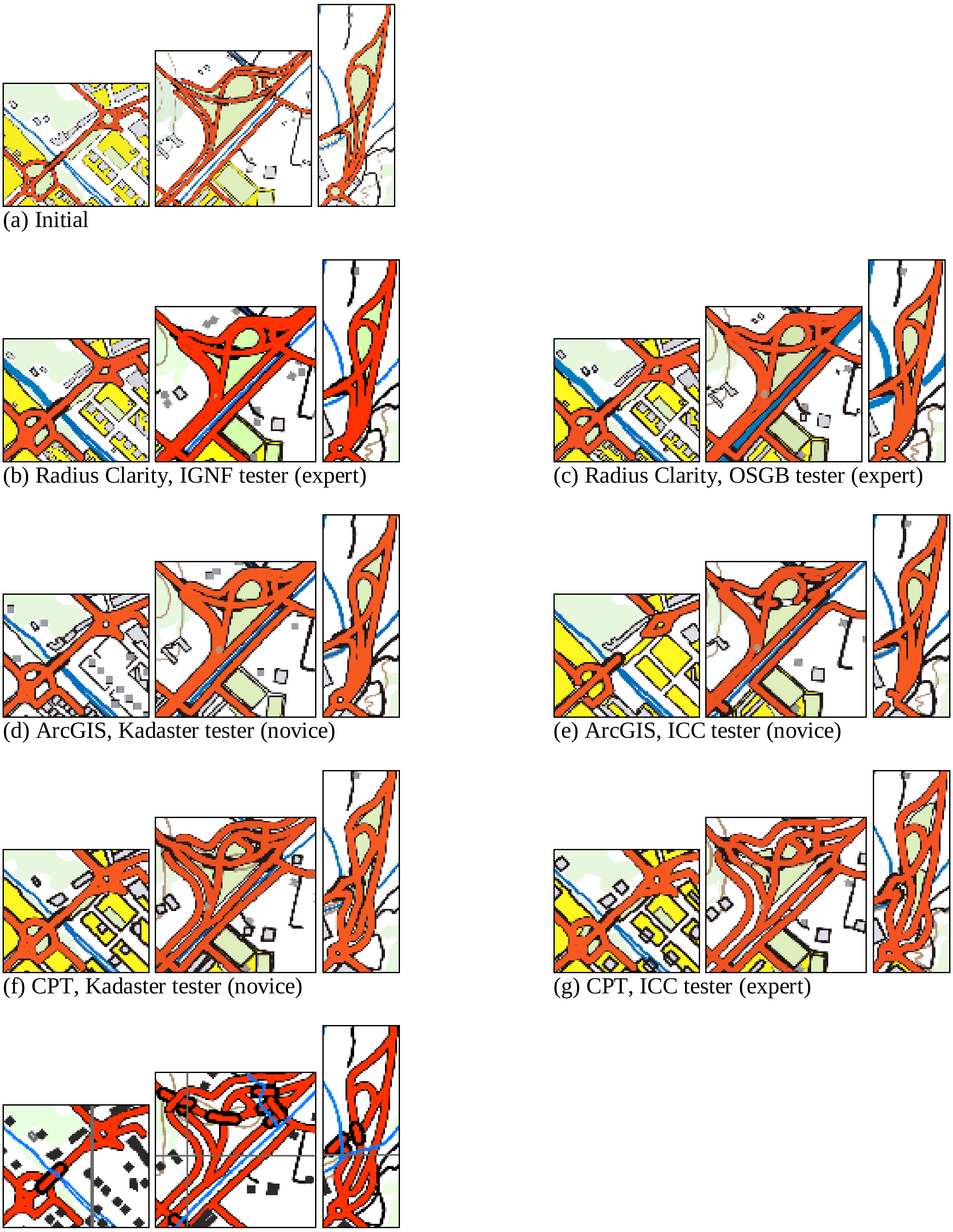
Jantien Stoter, TU Delft & Kadaster, The Netherlands
Blanca Baella, ICC, Catalonia
Connie Blok, ITC, Enschede, The Netherlands
Dirk Burghardt, TU Dresden, Germany
Francisco Dávila, IGN, Spain
Cécile Duchêne, IGN, France
Maria Pla, ICC, Catalonia
Nicolas Regnauld, Ordnance Survey, United Kingdom
Guillaume Touya, IGN, France

1 Introduction

This paper presents the results of the EuroSDR (European Spatial Data Research) research project that studied the state-of-the-art of automated generalisation in commercial software in a collaboration between National Mapping Agencies (NMAs), research institutes and vendors. The aims of the study were to learn more about generic and specific map requirements of NMAs, to show possibilities and limitations of commercial generalisation software, and to identify areas for further developments based on latest research advances.
The project consisted of three main steps: requirements analysis, testing, and evaluation.
The ***requirement analysis*** (carried out from Oct 2006 till June 2007) resulted in four representative test cases, formalised and harmonised NMA map specifications for automated generalisation as well as an analysis of the defined specifications that shows the similarities and differences between map specifications of different NMAs. The four NMAs who provided the test data are: Ordnance Survey Great Britain (OSGB), Institut Géographique National, France (IGNf), The Netherlands' Kadaster (Kadaster) and Institut Cartogràfic de Catalunya (ICC).
The ***testing*** was performed from June 2007 to Spring 2008 by project team members (from NMAs and research institutes) on out-of-the-box versions of four generalisation systems: ArcGIS (ESRI), Change/Push/Typify (University of Hanover), Radius Clarity (1Spatial) and axpand (Axes Systems). At the same time the vendors (except Axes systems) carried out tests with the same test cases with possibly improved and/or customised versions of their systems. The tests resulted in 35 outputs consisting of 700 thematic layers, where it should be noted that the effort to executer one test was approximately 1 week. Several example outputs with an extract of the same test case are shown in Figure 1.
The ***evaluation***, carried out from summer 2008 to spring 2009, consisted of an evaluation of meta aspects (based on information recorded by the testers) and of an evaluation of the generalised outputs themselves. The latter evaluation consisted of three parts that complemented each other: a) automated constraint-based evaluation, b) evaluation which visually compared different outputs for one test case and c) a qualitative evaluation of outputs by cartographic experts.
The methodology and intermediate results have been reported during previous ICA workshops on Generalisation and Multi-representation (Stoter et al, 2008; Burghardt et al, 2008; Burghardt et al, 2007), as well as in Stoter et al (2009). Final results have been published in the EuroSDR report on the project (Stoter et al, 2010) earlier this year.
This paper summarises the final EuroSDR report by presenting the main findings and conclusions because we assume that these are of specific interest for the ICA Commission on Generalisation and Multi-representation.
Section 2 and Section 3 summarise the answers to the two main questions of the research, which are:

1. What are the possibilities and limitations of commercial software systems for automated generalisation with respect to NMA requirements? (Section 2)
2. What different generalisation solutions can be generated for one test case and what are the reasons for these differences? (Section 3)

Section 4 presents the main conclusions of the research and identifies issues for further research.



(a) Initial

(b) Radius Clarity, IGNF tester (expert)

(c) Radius Clarity, OSGB tester (expert)

(d) ArcGIS, Kadaster tester (novice)

(e) ArcGIS, ICC tester (novice)

(f) CPT, Kadaster tester (novice)

(g) CPT, ICC tester (expert)

(h) CPT, CPT tester (vendor)

Figure 1 Initial data and test outputs for focus zone "complex junction" in ICC data set

2 Possibilities and limitations of commercial generalisation software

The following findings describe the possibilities and limitations of commercial software systems for automated generalisation taking into account NMA map requirements:

- All the tested systems offer potentials for automated generalisation, especially for handling constraints on single objects (in particular roads and buildings) (see also Figure 1). However only a few generalisation problems that were raised by the test cases appear to be fully solved by the out-of-the-box systems. This may be a result of the complex and very specific constraints that require customisation of the out-of-the-box versions. Apparently the tested systems provide generic solutions which are not directly applicable to the specific cases.

- In line with the first finding, generally the cartographic experts in the expert evaluation did not score the generalised outputs very high, with some exceptions (i.e. generalisation of individual objects and consistency between river and roads and spatial distribution for group of rivers). The experts scored the generalised outputs “bad” on *Information reduction.* (i.e. outputs were undergeneralized) because testers did not accept the unsatisfactory automated generalisation solutions. As a consequence, *Deviation from the* (original) *map* and *Preservation of geographic characteristics* scored relatively high. The outputs scored also not very well on *Legibility, Manual editing required, Number of main detected errors*, and *Number of main positive aspects*.
- The expert evaluation also identified noticeable differences between software systems and test cases, which may show the fitness for one system to handle the specificities of a given test case, examples are relatively high scores of CPT for minimum dimensions, granularity and quantity of information of buildings, as well as for minimum distance constraint. In case of preservation constraints, noticeable differences may also indicate situations that are not touched at all by some systems, where other systems did perform (some) generalisation. Examples are relatively high scores of axpand and Radius Clarity for shape and spatial distribution of contour lines, but they had not been generalised.
- Also for “classical” problems, not all needed functionalities are provided by the out-of-the-box systems. We can observe a general lack of contextual algorithms on groups of objects (typification, selection), which could be a result of the lack of contextual awareness of most of the out-of the-box solution. i.e. they do not adapt well to different contexts, and therefore some situations are well treated while others are not. Also functionalities for defining sensible groups of objects for generalisation (closely related to contextual algorithms) are missing. Displacement is only available in CPT (based on least squares) and axpand (based on snakes). In Radius Clarity, it is present (based on the “beams” (Bader & Barrault, 2001)) but not usable without customisation.
- For other classical problems, algorithms are present but either their parameterisation is difficult because it does not match well the way the specifications are expressed (e.g. line or area simplification, buildings aggregation), or there is a lack of tools to detect where to apply the algorithms (e.g. detecting conflicts and defining sensible groups through partitioning) and how to parameterise the algorithms and to control their effects (e.g. patterns detection, discrimination between urban and rural areas, etc.). It should be noted that once the parameters have been set, in practice they are used for a given product - meaning it may not be a major problem if it takes long to set them. Also for parameterisation it is true that customisation is required and that testing the out-of-the-box versions is not the "regular" way of NMAs setting their production lines (Lecordix et al, 2007; Baella & Pla, 2003).
- Many of the identified shortcomings have been studied in research and for some of them, solutions exist at NMAs. The lack of these solutions in commercial software may be due to different needs among NMAs (due to differences in data models and specifications). This implies on the one hand huge investments from the commercial vendors for a small numbers of potential customers, and on the other hand huge investments of NMAs to invest in partial solutions which still require considerable customisation effort.

The results may look disappointing. However they should be interpreted with care. First, the ambitions of the project were high: the generalisation requirements were defined through concise constraints, the test cases contained a selection of complex/known problems and the focus was on the production of high quality paper maps. One should be aware that the functionality available in the four systems does enable to automate part of the generalisation processes and to optimise the production workflows. Another relevant remark is that some of the shortcomings were tackled by the vendors in their parallel testing (buildings elimination and displacement algorithms in ArcGIS and Radius Clarity, for instance). In addition the vendors have indicated that this project has resulted in internal developments on automated generalisation. Also it is not a surprise that out-of-the box versions are not capable of directly fulfilling NMAs requirements. In fact the results confirm that customisation is definitely required to tune the capabilities of the systems to the requirements of specific test cases. Finally one should know that systems are used more satisfactory in practice (examples are included in Stoter et al, 2010). Also the NMAs in the project team have achieved some successful implementation with customised versions of the tested software.

3 Different generalisation solutions for one test case

Outputs for one test case can be very different, which was specifically identified and illustrated by the evaluation that compared different generalised outputs for one test case. This can be partly explained by differences in capabilities of systems. Other reasons for these differences are the following.

- Specifications provided by NMAs are sometimes fuzzy and do not express fully their actual requirements. They may be incomplete or they may focus on the most common, well known situations while ignoring (unknown) exceptions.
- A direct match between how constraints are specified and the concerning parameterisation in specific software is mostly missing. Understanding how a given system reacts to a specific situation and with respect to the defined constraints, requires quite experienced users. Therefore differences in outputs may have been caused by different expert levels of the testers with the systems. In addition testers familiar with the test data obtained other results than testers that were new to the data.
- Differences between testers' approaches. Some testers prefer outputs in which some constraints are very well satisfied and others very badly or in which some parts are very well generalised and some parts are very badly generalised. Other testers prefer outputs in which almost no generalisation was performed, but also no errors were generated.

4 Conclusions and further research

The experiences in the EuroSDR generalisation project confirm that the result of an automated generalisation process is not a linear process where the end result can be predicted starting from a specific source data set and specifications formalised in constraints. Instead the end result is influenced by many interchanging aspects such as richness of the data; content, formalisation level and fuzziness of the map specifications; the way the tester interprets the constraints; functionality selected by the tester; the parameterisation applied, etc.
The methodology applied in our research had to consider all these kinds of heterogeneity to guarantee independent testing and evaluation of available generalisation solutions. Consequently an important research aspect was the applied methodology itself: how to set up a case study for evaluating commercial generalisation software; how to specify both generic and NMA specific requirements for automated generalisation; how do automated generalisation processes work; how to perform evaluation of generalisation output; how does the constraint approach, as adopted in this research, work in practice?

Several topics have been identified for further research in automated generalisation. They are:

- Completing and refining map specifications as constraints, with specific attention for improving formalisation level (Zhang et al, 2008; Touya et al, 2010).
- Formalising and evaluating preservation specifications, i.e. how to formalise and measure the initial situation and how to formalise and measure the accepted change.
- Constraint-based generalisation and evaluation, e.g. weighting and prioritising, interaction between constraints, ignoring constraints to enable good results for other constraints, expressing constraint satisfaction in values ranging from 0 to 1, instead of in Boolean values, in order to extend the propositions of (Bard, 2004).
- Studying the appropriateness of constraints in generalisation. In some cases, specifying the expected transformation with constraints can help if this transformation is always the same and if it is well known. However fuzzy and incomplete constraints resulted in very different interpretations and solutions among the testers, which may ask for a different approach in defining the requirements for automated generalisation.

To improve and reuse the project methodology, it is also recommended to evaluate generalisation software on criteria beyond constraints in a future project:

- User-friendliness of parameterisation (availability of tools to select identical situations to be generalised with the same parameterisation like the one proposed by (Hubert, 2002) or tools for situation dependent automated parameterisation).
- Scalability of the systems by testing with large amounts of data to address issues such as performance, computational complexity, potential memory overflows (that necessitate data partitioning) or presence of numerous and various particular cases that make some algorithms fail.
- Quantify customisation possibilities. The most realistic way to address NMA-specific requirements may be to customise existing software. This requires facilities for writing extensions or for allowing integration with other systems.

In conclusion, all the tested software systems provide tools for automated generalisation, but none of them achieves globally good results. Despite the current limitations, they can be implemented in a production workflow to automate considerable part of the generalisation process.

Solving the lack of complete solutions in commercial software requires a huge investment from the commercial vendors, considering the small number of potential customers, and a huge effort of NMAs in the customisation of partial commercial solutions to fulfil their specific requirements. Therefore stronger and deeper knowledge flow between researchers, vendors and NMAs, as operated in this project, is essential to progress in the automation of generalisation.

A significant contribution of this project to generalisation research is the methodology to define map specifications for automated generalisation and to evaluate generalised data. Consequently, future generalisation research can extend our methodology and make use of our findings, applying improved versions of the constraints sets and re-using our carefully sourced generalisation test cases.

Acknowledgments

The project could never have been realised without the help of many people.

First, many thanks go to the vendors who participated in the project. They are: Axes Systems (Mary Lou von Wyl and Ajay Mathur), ESRI (Dan Lee, Jean-Luc Monnot, Paul Hardy, John van Smaalen, David Watkins), University of Hannover (Monika Sester) and 1Spatial (Martin Gregory). They provided their software for the tests, performed parallel tests and supported the project team testers during the tests.

Also the different testers from the partner organisations were indispensable for this project. They are (apart from the project team members, who co-author this paper): Magali Valdepérez (IGN, Spain), Patrick Revell (OS, UK), Stuart Thom (OS, UK), Sheng Zhou (OS, UK), Willy Kock (ITC, NL), and Patrick Taillandier (IGN, France).

Finally, we would like to thank all persons who have been temporary involved in the project team while the project was running. They are: Karl-Heinrich Anders and Jan Haunert (former University of Hannover), Nico Bakker, Annemarie Dortland and Peter Lentjes (Kadaster, NL), Peter Rosenstand (former KMS, Denmark), Stefan Schmid (former student, University of Zurich), Maarten Storm and Harry Uitermark (Kadaster, NL) and Xiang Zhang, ITC, Enschede, NL.

References

Bader, M., Barrault, M., Weibel, R. (2005) Building displacement over a ductile truss. In: International Journal of Geographical Information Science, Volume 19, Issue 8, pp 915-936.

Baella, B., Pla, M. (2003) An example of database generalization workflow: The topographic database of catalonia at 1:25 000. In: 5th Workshop on Progress in Automated Map Generalization. ICA, Paris, France.

Bard, S. (2004) Quality assessment of cartographic generalisation. In: Transactions in GIS, Volume 8, Issue 1, pp 63-81.

Burghardt, D., Schmid, S., Duchêne, C., Stoter, J.E. (2008) Methodologies for the evaluation of generalised data derived with commercial available generalisation systems. In: Proceedings of the 11th ICA workshop on generalisation and multiple representation, 20-21 June 2008, Montpellier. 16 p

Burghardt, D., S. Schmid, J.E. Stoter (2007). Investigations on cartographic constraint formalisation, Notes in: proceedings of the workshop of the ICA commission on generalization and multiple representation, August 2-3 at the 23nd international cartographic conference ICC: Cartography for everyone and for you, 4-10 August 2007 Moscow, Russia. 16 p.

Hubert, F. (2002) Map samples to help GI users specify their needs. In: Proceedings of 13th International Symposium on Spatial Data Handling (SDH'08), 9-12 July, Ottawa, Canada.

Lecordix, F., Le Gallic, J-M., Gondol, L. (2007) Development of a new generalisation flow line for topographic maps. In: Proceedings of the 10th ICA workshop on generalisation and multiple representation, Moscow.

Mackaness, W.A. and A. Ruas (2007). Evaluation in Map Generalisation Process, Chapter 5 in Generalisation of Geographic information: cartographic modelling and applications, edited by W.A. Mackaness, A. Ruas and L.T. Sarjakoski, pp 89-112. Elsevier. ISBN 978-0-08-045374-3

Ruas, A. (2001), Automatic Generalisation research: Learning process from interactive generalisation, OEEPE, Report nr 39.

Stoter, J.E., D. Burghardt, C. Duchêne, B. Baella, N. Bakker, C. Blok, M. Pla, N. Regnauld, G. Touya, S. Schmid (2009). Methodology for evaluating automated map generalization in commercial software, Pages 311-324 In: Computers, Environment and Urban Systems Volume 33, Issue 5, September 2009.

Stoter, J.E., B. Baella, C. Blok, D. Burghardt, C. Duchêne, M. Pla, R. Regnauld, G. Touya, State-of-the-art of automated generalisation in commercial software. IN PRESS. EuroSDR series on research projects. Published by Gopher, Amsterdam, The Netherlands.
Also online available: http://www.eurosdr.net/projects/generalisation/eurosdr_gen_final_report_mar2010.pdf

Stoter, J.E., Burghardt, D., Schmid, S., Duchêne, C., M. Pla, N. Regnauld, B. Baella (2008). A study on the state of the art automated map generalisation implemented in commercial out of the box software. In: Proceedings of the 11th ICA workshop on generalisation and multiple representation, 20-21 June 2008, Montpellier. 15 p.

Touya, G., Duchêne, C., Ruas, A., 2010. Collaborative Generalisation: Formalisation of Cartographic Knowledge to Orchestrate Different Generalisation Processes. In: GIScience'2010. Zurich. Accepted as full paper.

Zhang, X., Stoter, J., Ai, T. And Kraak, M.J. (2010) Formalization and data enrichment for automated evaluation of building pattern preservation, In: Spatial Data Handling 2010, Hong Kong. Accepted as full paper.