GENERALISATION OPERATORS FOR PRACTICE – A SURVEY AT NATIONAL MAPPING AGENCIES

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ABSTRACT
Generalisation operators are one of the building blocks in automated generalisation. There is no research effort which addresses the status and the demands of NMAs towards those generalisation operators. This was the starting point to investigate this issue within a survey. This paper reports on the survey and its results. The survey is two fold, by firstly investigating the current situation of the generalisation process at the NMAs and by secondly elaborating on the importance and the problems of specific operators regarding the different scales individually supplied by the NMA. Based on the survey the paper gives some recommendations and thereby provides some interesting insights for the research community, NMAs and software suppliers about the demands of NMAs in the context of generalisation operators.

KEYWORDS: National Mapping Agency, survey, generalisation operator, automated generalisation

1 Introduction

Automated generalisation of topographic data is an urgent issue for NMAs because of cost reduction, changing markets and increasing update cycles. By now there is no full automated solution available. Different research projects described the current status and investigated the specific challenges towards automated generalisation, such as Rieger & Coulson (1993), Ruas (2001), Stoter (2005) and Stoter et al. (2008).

All of these projects focused on the lack of automated generalisation from different perspectives. According to these studies the difficulty of implementing full automated generalisation is manifold and is caused by for instance the lack of formalization and the high complexity of data. Additionally the difficulty is strongly related to the fact that it is hard to define a generic generalisation process applicable to (m)any topographic data set(s). However it is relevant to see if communalities can be discovered between NMAs in required generalisation operators, in the experienced difficulties of such operators and in the lack of the availability of those operators. So far such an analysis is not yet available. Generalisation operators influence the outcome of the generalisation process heavily and are one of the building blocks for automated generalisation. Additionally data providers such as NMAs still have the most experience and overview of generalisation operators, as they apply the operators in a production environment (real world cases in contrast to the laboratory situations as implemented in research). This was the starting point to set up a survey with the title - *the current problems of automated generalisation of topographic data at National mapping agencies*. It was filled in by eleven NMAs from 8 countries (complete list of NMAs can be found in the Acknowledgements). The reason for approaching NMAs was that they have a long tradition in generalisation and are one of the major bodies conducting practical work in this field.

The aim of the survey was to get insight into missing generalisation functionality and as such to give recommendations for future development of generalisation solutions for NMAs, software suppliers and the research community. This is also interesting for the generalisation community focusing on Web Services, as this will give indications, which operators are most important and most crucial to make accessible.

The structure of the survey was two-fold. The first part addressed the kind of implementation of the generalisation process of topographic products at the specific NMAs (model vs. cartographic generalisation) and their degree of automation but does not address the operators as such. The second part aimed at the importance and the problems regarding specific generalisation operators in combination with feature types. This second part addresses those issues for each scale transition per NMA separately. Especially this part aimed gaining insights into the current problems of generalisation operators and at what scale transition(s) they occur.

The paper is structured as follows. The next section introduces related research in the context of surveys on automated generalisation. Section 3 will introduce the structure of the survey and explain some terms, which have been used in the survey. The results of the survey will be summarized in Section 4. The paper will conclude the survey in the last section and give some recommendations for future developments on automated generalisation.

2 Related literature

Research about automated generalisation has yielded a lot of concepts and applications in the last 20 years. A good overview can be found in McMaster & Shea (1992) or in the most recently published book of Mackaness et al. (2007). Different views on generalisation have been developed, such as the generalisation model by Gruenreich (1992), which separates generalisation into *model generalisation* and *cartographic generalisation* (Figure 1). Model generalisation is concerned with the transformation of data according to a target model and cartographic generalisation aims at producing usable maps out of data by avoiding cartographic conflicts.

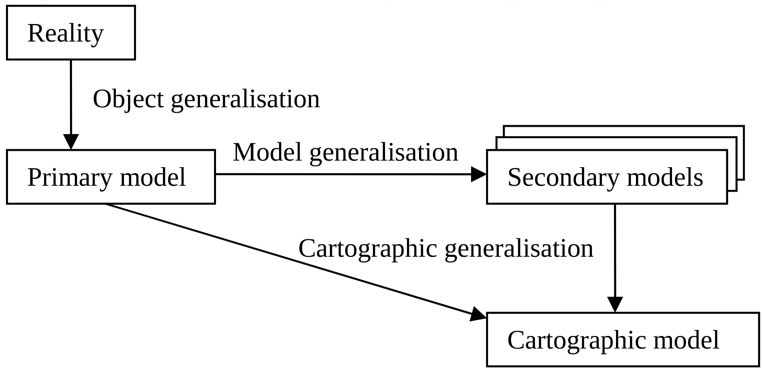

Figure 1: Generalisation model of Gruenreich (1992).

Cartographic generalisation is applied to solve conflicts of cartographic features on the map. Cartographic features do already have some symbolization attached. The relation of cartographic generalisation and symbolization is depicted in Figure 2.

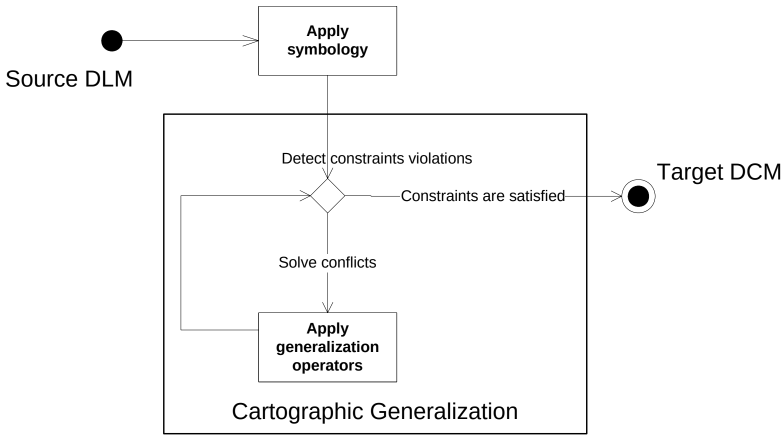

Figure 2: Cartographic generalisation process.

Besides the concepts for automated generalisation different initiatives studied automated generalisation empirically. For instance Rieger & Coulson (1993) found out, that the classification of generalisation operators differs depending on the specific cartographer and that a common sense on such a classification does not exist. Ruas (2001) investigated within the OEEPE project the state-of-the-art generalisation by evaluating different interactive generalisation software packages. The tests performed within this project were specific to generalisation algorithms and some test datasets. A general overview of the challenges of NMAs regarding automated generalisation within the coming future has been described by Stoter (2005). Brewer & Buttenfield (2007) ran map exercises with students on different datasets at various scales. The results of the exercises were compiled to the so called ScaleMaster, which provides guidelines for generalisation processes. Within the currently ongoing EuroSDR project about *Research on the state-of-the-art of generalisation*, the capabilities of several generalisation systems are being tested (Stoter et al. 2008).

The survey described in this paper actually supports and extends the general overview of Stoter (2005), by investigating the operator-specific demands of NMAs to establish automated generalisation of topographic datasets. It also contributes to the efforts of the OEEPE study and the EuroSDR project by providing a more abstract view on the current challenges of automated generalisation of topographic data.

3 Description of the survey

This section describes the structure of the survey. As mentioned before, the survey was two-fold. The first part addressed the overall setup of the production line generated by (semi-)automated generalisation. Especially it focused on how the generalisation process is implemented. At the first place, if the generalisation is implemented as two separated processes for producing data (model generalisation) and maps (cartographic generalisation) and for which reasons. Additionally the survey asked, if the NMAs take cartographic issues into account while performing model generalisation and if yes, which cartographic operators are applied. Another aspect addressed by the survey is to what degree the automation is already implemented. The participants were asked to rate the degree of automation of the current generalisation process, regarding three consecutive stages:

1) *Modeling* is concerned with the design of the processes and the preparing/preprocessing of the data.
2) *Execution* performs the transformation of the objects.

3) *Evaluation* receives the transformed objects and checks the quality of the entire process as a final step.

The degree of automation is defined in this survey as the advantage in time over the (former) manual/interactive process. In the first part of the survey the participants were also asked to rate the demanding issues to gain full automation in generalisation. Demanding issues are those which are important, but are not yet solved. The participants could rate the demanding issues based on this set of demanding issues:

- generalisation algorithms
- algorithms for pattern and conflict detection
- appropriate mechanisms for orchestration of the algorithms.

The second part of the survey addressed the importance and problems of specific operators in relation to the specific scale of each of the delivered products. The degree of importance indicates how important a specific operator is to achieve successful generalisation processing (i.e. plays a major role in the current process). In a second step problems of operators are rated based on the degree of difficulty to achieve automated generalisation processing successfully.

In order to have a foundation for the survey we applied classifications for operators (Foerster et al. 2007) and topographic feature types. The operator classification (Table 1) separates between model and cartographic generalisation and excludes symbolization as an integral part of the generalisation part (cf. Figure 2, Section 2). The classification of the topographic feature types (Table 2) is inspired by a list of feature types of the EuroRegionalMap (Delattre, 2004).

Model generalisation	Class Selection
	Reclassification
	Collapse
	Combine
	Simplification
	Amalgamation
Cartographic Generalisation	Enhancement
	Displacement
	Elimination
	Typification
	Enlargement
	Amalgamation

Table 1: Classification of generalisation operators applied in the survey based on Foerster et al. (2007).

Administration
Buildings
Railways
Roads
Relief
Lake
River
Coastal feature
Landcover

Table 2: Classification of topographic feature types applied in the survey.

The survey also incorporated a glossary, which introduced the generalisation model of Gruenreich (1992) and the applied operator classification (Foerster et al., 2007) to provide the participants background information on the operators used in the survey. This ensured a level of common understanding of the participants, which is beneficial for comparing the survey results of different participants and thus indispensable for drawing strong conclusions based on the survey.

4 Results of the survey

This section presents the results of the survey and relates the results of particular questions in order to give a comprehensive analysis. The values of the tables presented in this section are all compiled by the arithmetic mean. It is important to note, that the German NMAs are treated as separate entities in the survey. At first instance we intended to group the answers of the German NMAs to avoid a certain influence in the survey. However this was not possible as their answers (regarding supplied scales and production environment) were too heterogeneous.

4.1 Survey part on the production setting

Looking at the production process, 2/3 of the participants apply separate processes for producing data (model generalisation) and maps (cartographic generalisation). More of half of the participants do this to ease the production process (i.e. reducing the complexity). Also a half of the participants answered, that producing data is their reason for separating the issue. One NMA stated that the process is separated due to internal use (military mapping) of the data (IGN France) and specific requirements of the software environment (Swiss Topo).

However the separation between model and cartographic generalisation does not seem to be that strict. At least a half of the participants answered, that they take into account cartographic issues while performing model generalisation. Looking at the different cartographic generalisation operators, which they apply during their model generalisation process most of them (2/3) apply amalgamation and elimination based on cartographic characteristics. This shows that during model generalisation cartographic characteristics regarding map space and readability are considered to be important. Another reason for this overlap might be the classification of the operators itself. However, this cannot be checked, but is important to note.

The participants rated the current degree of automation of their production processes, according to globally looking at model and cartographic generalisation and the different stages of modeling, execution and evaluation.

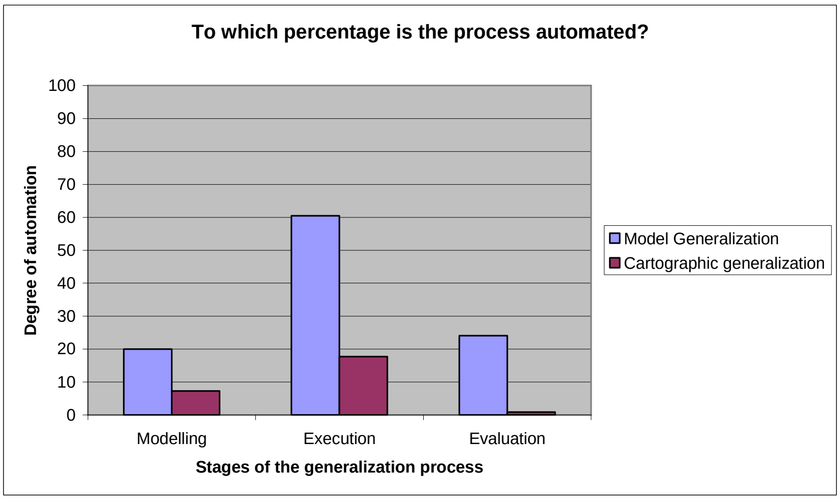

Figure 3: Degree of automation of generalisation regarding the different process stages.

Looking at the result (Figure 3), it becomes clear, that model generalisation has the highest degree of automation. The execution has the highest degree of automation compared to the other stages.

Comparing the most demanding issues in order to achieve full automation (rated from 0 not demanding to 5 most demanding), the issues[1] related to cartographic generalisation are more demanding (Figure 4). However, no specific demand for one of the three stages is so extraordinary high, that we can make further assumptions or give specific recommendations. Nevertheless, there is a slightly higher demand for currently missing generalisation algorithms aiming at the execution of cartographic generalisation.

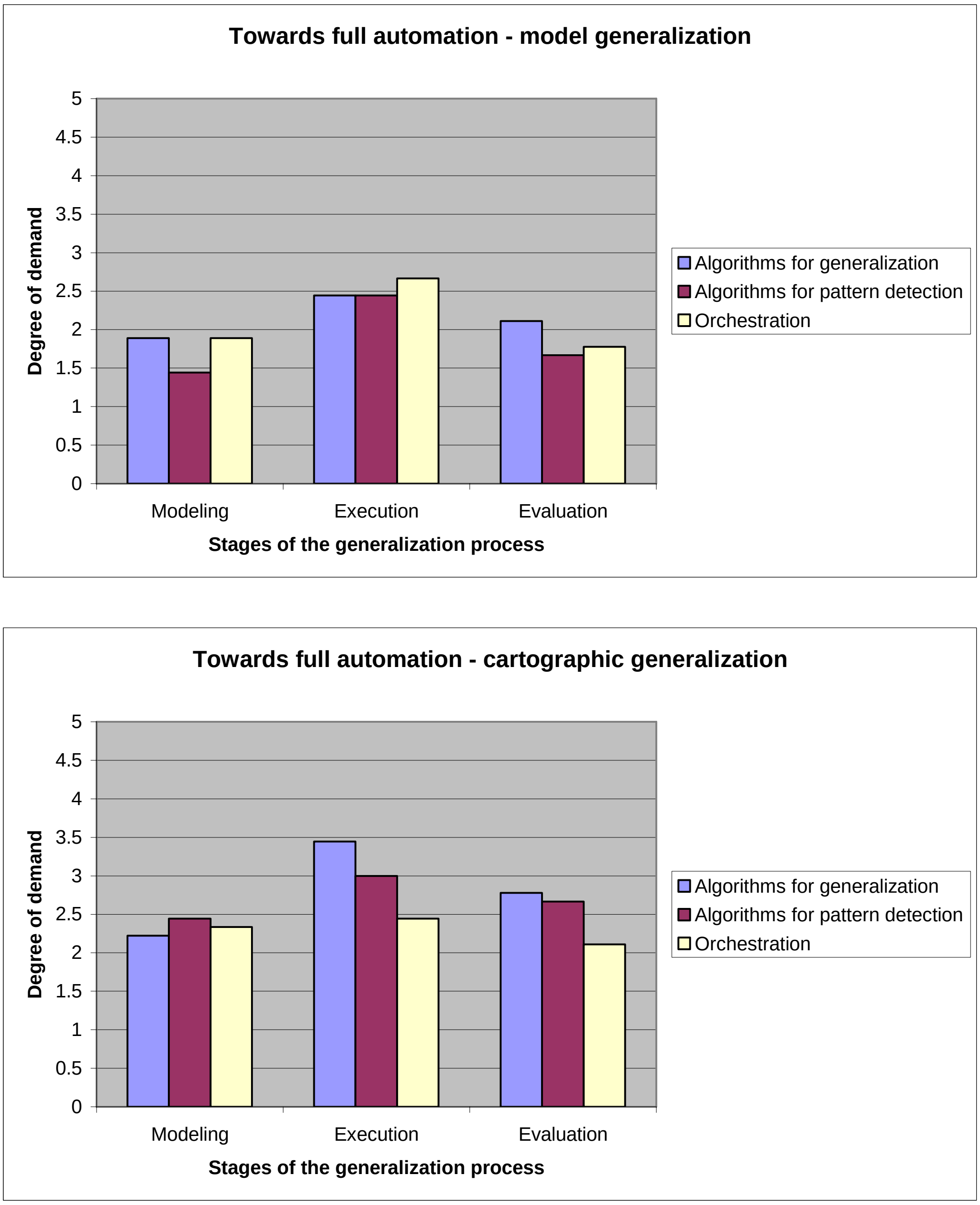

Figure 4: The different demands regarding model generalisation (top chart) and cartographic generalisation (bottom chart).

[1] For detailed description of the issues cf. Section 3.

4.2 Scale-related survey part

In the second part of the survey, the participants were asked about their production line and the occurring problems related to operators and scales. The participants were requested thereby to fill in the survey separately for each scale transition for which they apply generalisation. Figure 5 gives an overview on how many answers we received for the different scale transitions. Most answers addressed the common transition from 1:10K to 1:50K (supplied by 4 participants). Also 1:50K to 1:100K and 1:50K to 1:250K are frequently supplied (3 participants). In the following section, we will only cover those scale transitions, as the other scales are not so frequently supplied and do not provide a strong basis to deduce sufficient assumptions.

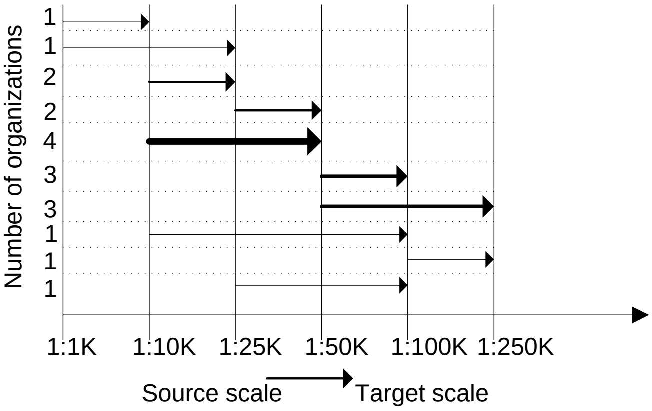

Figure 5: Overview of the different scale transitions at which the participants apply any generalisation and the number of received answers.

To get more insight on what type of information is represented on the map related to a specific scale, the participants were asked to indicate the importance of the most frequently used topographic feature types versus the three basic geometry types. We used an importance rating (0 (no importance) – 5 (high importance)), which indicates how important specific feature types are in connection to specific geometry types. Overall this allows us to assume which feature types are present on the map (or in the data) (Table 3). It becomes clear, that feature type building and landcover are important at larger scale, but do not play any role at smaller scales. Maps (or data) at larger scale consist mainly of lines and polygons, but that differs at smaller scales at which maps tend to consist more of lines.

	1:10K - 1:50K			1:50K - 1:100K			1:50K - 1:250K		
	Point	Line	Polygon	Point	Line	Polygon	Point	Line	Polygon
Administration	0.0	1.0	1.8	0.0	1.3	1.7	0.0	1.3	2.7
Building	2.3	0.0	4.5	1.7	0.0	2.7	3.0	0.0	1.7
Railways	0.5	5.0	0.0	0.7	4.3	0.0	1.7	4.0	0.0
Roads	0.3	5.0	1.0	0.3	5.0	0.0	1.7	5.0	0.0
Relief	1.5	1.8	0.0	1.3	1.7	0.0	1.7	1.3	0.0
Lake	0.0	1.3	3.0	0.7	0.0	3.7	0.7	0.0	3.0
River	0.0	4.8	1.3	0.0	4.3	1.7	0.0	4.3	3.3
Coast	0.0	3.3	1.0	0.0	2.7	1.3	0.0	3.0	2.0
Landcover	0.0	0.0	4.0	0.0	0.0	3.0	0.0	0.0	2.7

Table 3: Importance of feature types versus geometry types related to scale.

As mentioned before, for the survey we applied the operator classification of Foerster et al. (2007) to investigate the importance of specific operators and the most problematic ones. Table 4 and Table 5 give an overview of the importance of operators in relation to the different feature types. Table 4 describes the importance of model generalisation operators, whereas Table 5 describes the importance for cartographic generalisation operators. The importance of model generalisation operators and cartographic generalisation operators differs in relation to scale for the NMAs. The importance of model generalisation is considered to be significantly high at scale transition at smaller scales (1:50K – 1:250K). However, the importance of cartographic generalisation operators is higher at larger scales (1:10K – 1:50K). Regarding the survey the most important operators are considered to be Simplification, Amalgamation (model generalisation) and Displacement.

	1:10K - 1:50K						1:50K - 1:100K						1:50K - 1:250K					
	Collapse	Combine	Amalgamation	Reclassification	Class Selection	Simplification	Collapse	Combine	Amalgamation	Reclassification	Class Selection	Simplification	Collapse	Combine	Amalgamation	Reclassification	Class Selection	Simplification
Administration	0.0	0.0	0.8	0.3	0.0	1.5	0.0	0.0	1.5	0.5	0.0	2.0	0.0	0.0	3.0	1.0	0.0	4.0
Buildings	1.8	1.0	3.0	1.0	0.5	2.0	1.5	0.0	2.0	1.0	1.0	2.0	3.0	0.0	3.0	2.0	2.0	2.0
Railways	1.8	0.0	0.5	0.3	0.5	0.8	0.0	0.0	1.0	0.5	1.0	1.5	0.0	0.0	2.0	1.0	2.0	2.0
Roads	3.5	0.0	1.0	0.3	1.3	1.0	0.0	0.0	2.0	2.0	1.0	2.0	0.0	0.0	4.0	3.0	2.0	4.0
Relief	0.0	0.3	0.0	0.0	0.5	0.8	0.0	0.5	0.0	0.5	1.0	1.5	0.0	0.0	0.0	0.0	2.0	3.0
Lake	0.0	1.0	1.8	0.0	0.5	0.8	0.0	0.0	1.5	0.0	1.0	1.5	0.0	0.0	3.0	0.0	2.0	3.0
River	1.0	0.0	0.8	0.8	1.3	1.0	2.0	0.0	1.5	0.5	2.0	2.0	4.0	0.0	3.0	1.0	2.0	4.0
Coastal feature	0.0	0.0	0.8	0.0	0.5	1.5	0.0	0.0	1.5	0.0	1.0	1.5	0.0	0.0	3.0	0.0	2.0	3.0
Landcover	0.0	0.0	1.3	3.0	1.3	1.8	0.5	0.0	2.5	4.0	1.0	2.0	1.0	0.0	4.0	4.0	2.0	4.0

Table 4: Importance of model generalisation operators versus feature types related to scale.

	1:10K - 1:50K						1:50K - 1:100K						1:50K - 1:250K					
	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation
Administration	0.3	0.0	2.3	0.0	0.0	1.0	1.0	0.0	3.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	1.0
Buildings	3.7	4.3	5.0	2.7	4.7	3.3	2.3	2.7	4.3	1.7	4.3	2.3	1.3	0.3	2.0	0.7	2.0	0.7
Railways	0.3	1.3	3.0	1.0	1.7	1.3	0.7	1.3	4.0	1.3	0.7	1.3	1.0	1.7	3.3	1.0	0.0	0.7
Roads	1.7	1.7	3.7	3.0	2.0	1.3	2.3	1.7	4.7	1.7	2.7	1.3	1.7	1.7	3.7	2.0	2.3	1.3
Relief	1.7	0.7	1.0	0.7	0.3	0.0	1.7	0.7	1.7	0.7	0.3	0.0	1.0	0.7	1.0	1.0	0.3	0.0
Lake	1.7	0.7	0.3	1.7	1.7	2.3	1.0	1.3	0.3	1.3	1.0	2.0	0.3	0.3	0.3	1.0	1.3	1.7
River	1.7	0.7	1.3	1.7	1.0	1.0	1.7	0.7	3.0	1.7	1.0	1.0	1.0	0.7	2.0	1.3	1.0	1.3
Coastal feature	1.0	0.0	0.3	1.3	1.0	1.0	0.7	0.0	0.3	1.3	1.3	1.0	0.7	0.7	0.7	0.7	0.7	1.0
Landcover	1.7	1.3	1.0	1.7	1.0	3.0	1.3	0.7	1.0	1.3	1.0	2.7	1.0	0.7	0.3	2.0	0.7	1.3

Table 5: Importance of cartographic generalisation operators versus feature types related to scale.

The difficulty of specific generalisation operators to achieve successful generalisation processing in relation to a specific feature type and scale is depicted in Table 6 and Table 7. The model generalisation operators do not show any problem. This goes in line with the high percentage value of automated execution of model generalisation processes (Figure 3). Contrary, the cartographic generalisation operators are more problematic for current production lines. The most problematic operators are Displacement and Typification.

	1:10K -1: 50K						1:50K-1:100K					
	Collapse	Combine	Amalgamation	Reclassification	Class Selection	Simplification	Collapse	Combine	Amalgamation	Reclassification	Class Selection	Simplification
Administration	0.0	0.0	0.3	0.3	0.0	0.5	0.0	0.0	0.5	0.5	0.0	1.0
Buildings	0.8	0.0	1.0	0.3	0.3	1.0	0.5	0.0	1.0	0.5	0.0	2.0
Railways	1.3	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.5	0.0	0.0	0.5
Roads	2.5	0.0	0.5	0.0	0.5	0.3	0.0	0.0	1.0	0.0	0.0	1.0
Relief	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.5
Lake	0.0	0.0	0.3	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	1.0
River	0.5	0.0	0.3	0.0	0.5	0.5	0.0	0.0	0.5	0.0	0.0	1.0
Coastal feature	0.0	0.0	0.3	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	1.0
Landcover	0.0	0.0	1.0	0.5	0.5	1.0	0.0	0.0	2.0	0.5	0.5	2.0

Table 6: Most problematic model generalisation operators (no answers for 1:50K-1:250K available).

	1:10K - 1:50K						1:50K - 1:100K						1:50K - 1:250K					
	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation	Enhancement	Enlargement	Displacement	Elimination	Typification	Amalgamation
Administration	0.0	0.0	3.3	0.0	0.0	0.3	0.3	0.0	3.0	0.0	0.0	0.3	0.0	0.0	3.0	0.0	0.0	0.5
Buildings	3.3	1.7	4.7	2.3	5.0	2.7	3.0	1.3	3.7	1.3	4.0	1.7	1.0	1.0	3.0	1.5	2.5	1.0
Railways	0.0	0.0	3.3	0.0	0.0	0.3	0.3	0.0	3.0	0.0	0.0	0.3	0.0	1.0	4.5	1.5	0.5	0.5
Roads	1.7	0.8	4.0	1.2	2.5	1.5	1.7	0.7	3.3	0.7	2.0	1.0	0.5	1.0	4.5	3.0	3.5	1.0
Relief	1.1	0.6	3.8	0.8	1.7	1.1	1.2	0.4	3.2	0.4	1.3	0.8	2.5	0.0	0.5	1.5	0.5	0.5
Lake	1.7	0.8	4.0	1.2	2.5	1.5	1.7	0.7	3.3	0.7	2.0	1.0	0.5	0.5	1.0	1.5	2.5	0.5
River	0.9	0.5	3.7	0.6	1.4	1.0	1.1	0.4	3.2	0.4	1.1	0.7	0.5	0.5	4.0	3.0	0.5	0.5
Coastal feature	1.5	0.7	3.9	1.0	2.2	1.4	1.5	0.6	3.3	0.6	1.8	0.9	1.0	0.0	0.5	1.5	0.5	0.5
Landcover	1.2	0.6	3.8	0.9	1.9	1.2	1.3	0.5	3.2	0.5	1.5	0.8	2.0	0.5	0.5	3.0	0.5	2.0

Table 7: Most problematic cartographic generalisation operator.

5 Conclusion

The survey presented in this paper provides an overview of the currently applied strategies for automated generalisation and an analysis of the most important and most problematic generalisation operators. The results of each of those parts are complementary to each other and allow extracting a guideline for the research community and software developers. The major observations are that the model generalisation process is far more automated and advanced than the cartographic generalisation process. The importance of the operators as indicated by the NMAs shows that for a successful generalisation process, lots of different operators are involved. The most problematic operators during the generalisation process are Displacement and Typification.

Based on the survey, we can consider that advanced algorithms for cartographic generalisation are the major requirement of NMAs in the future. Additionally this seems to be the field, in which software suppliers could contribute most successfully. The need for more cartographic generalisation algorithms is finally an interesting aspect in relation to the development of Web Generalisation Services and a common research platform, because based on Web Services such advanced algorithms could be easily integrated into NMAs' generalisation software. In order to advertise the use of Web Service architectures (Burghardt et al. 2005, Foerster & Stoter 2006) in upcoming NMAs' generalisation software, it could be promising to integrate advanced algorithms for cartographic generalisation in the evolving research platform (Foerster et al. 2008).

In the near future, the analysis of the survey will be extended to investigate more thoroughly the links between the different issues addressed in the survey (e.g. rate the problematic operators by the value of their importance).

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- LVG Bavaria (German Bundesland)
- LVA Baden-Wuerttemberg (German Bundesland)
- BKG Germany
- NLS Finland
- IGN Belgium
- IGN France
- OS Ireland
- KMS Denmark
- Swiss Topo
- TDK, the Netherlands.

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