Improving Map Generalisation of Buildings by Introduction of Urban Context Rules

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1. Motivation

The number of national mapping agencies that use semi- and full-automated map generalisation approaches into map production increases steadily (Stoter 2005). The introduction of automated generalisation processes in map production systems requires the generalisation system to be capable of processing large amounts of map data in acceptable time and that results have a cartographic quality similar to traditional map products. In order to meet the latter requirement it is necessary to transfer the cartographic knowledge to the machine. Two possibilities exist for that purpose: First, the formalisation of the human knowledge in terms of expert rules; second, the use of machine learning techniques, which learn rules by statistical inference of actions of the cartographer or other machines. The focus of this work is on extending existing knowledge for the control of the map generalisation process by application of expert rules. Our hypothesis is that the introduction of expert rules into the generalisation process will help to improve the system performance in terms of efficiency and effectiveness. To test our hypothesis we will specifically examine the knowledge used for the generalisation of individual buildings for the scale transition from 1:10,000 to 1:25,000.

2. The Current Approach to Generalise Buildings

Map generalisation systems can be said to consist of four logical components: *constraints, measures*, *algorithms* and the generalisation *control* mechanism. Thereby the control mechanism realises the decision making, e.g. when and how to generalise, by evaluation of constraints and triggering of generalisation algorithms. In the following subsections we will discuss the components with respect to building generalisation.

2.1 Constraints and Operations for Building Generalisation

A map should meet two basic objectives: First, the map should be designed to fulfil a specific purpose, and second, the map must be legible. While the first objective imposes constraints on the semantics of the map the second objective imposes mainly geometric constraints. With respect to buildings the legibility constraints focus exclusively on the geometrical aspects. Commonly six constraints, ensuring legibility, are identified (AGENT Cons. 1998) and shown in fig. 1: (C1) minimum building size, (C2) building outline granularity, (C3) wall squareness, (C4) minimum internal width, (C5) minimum distance between two buildings, and (C6) the building density preservation constraint. These six constraints are also called active constraints since they can trigger a generalisation operation if they are not fulfilled. In contrast passive constraints are used to prevent strong changes resulting from operations induced by active constraints. With respect to a single building we identified three passive constraints. The concavity constraint should prevent strong changes of the building shape (C7). The positional accuracy constraint (C8) should prevent that a building's position is changed too much during building displacement that was triggered due to a violation of the minimum distance constraint. Finally a third constraint for a single building is to prevent the elimination of (semantically) important buildings (C9).

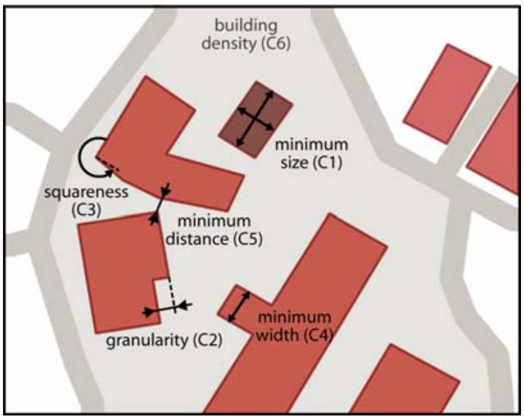

Figure 1. Active conditions on buildings.

Several operations can be activated if one of the previous listed constraints is violated. An extensive listing of cartographic operations to meet the legibility constraints is presented by McMaster and Shea (1992). For the generalisation of buildings, those operations focus either on the elimination, or the geometrical transformation of buildings. Note that in automated generalisation one cartographic operation, e.g. a building displacement, can be realised with different algorithms which base on different solution approaches. A list of generalisation algorithms is given in table 1.

Generalisation Algorithm	Applicable to constraints:	Author
Scale polygon	C1	---
Simplify building outline	C2	Regnauld et al. (1999)
Building wall squaring	C3	Regnauld et al. (1999)
Enlarge width locally	C4	Regnauld et al. (1999)
Simplify to rectangle	C2, C3, C4	AGENT Cons. (1999)
Enlarge to rectangle	C1, C2, C3, C4	AGENT Cons. (1999)
Eliminate building	C1, C5, C6	---
Typify buildings	C5, C6	e.g. Burghardt and Cecconi (2007)
Displace building	C5	e.g. Ruas (1998)

Table 1. Algorithms for building generalisation.

2.2 Controlling Building Generalisation

We need to formalise the relation between operations and constraints in order to make it amenable to an automated generalisation approach. Two general approaches exist. One approach is to use rules, with the well known schema *If (condition is true) Then (action A) Else (action B)*. The second approach is the so-called *constraint based approach*, used in our experiments. Here, a condition does not necessarily follow an action (Harrie and Weibel 2007). The advantage is that several cartographic constraints (i.e. conditions) can be evaluated first and afterwards it will be decided on the appropriate action (i.e. algorithm) to solve the given problem. To achieve a solution every constraint proposes zero, one or several actions – so called *plans* – to solve a particular problem. After all existing constraints have been evaluated, a ranking between all proposed plans is made and finally the most promising algorithm is triggered.

This constraint approach can be implemented in an agent-based system, where every building will be an agent. Here, the building "knows" the (legibility) constraints which it must fulfil. The process schema of the generalisation of such a building agent is shown in fig. 2. This process realises a "trial and error" approach, just like a cartographer works. Thereby, a building is generalised several times and every generalisation solution (a so called *state*) is characterised by a *happiness* value. The *happiness* value is calculated as weighted average of the constraint *satisfaction* values over all constraints.

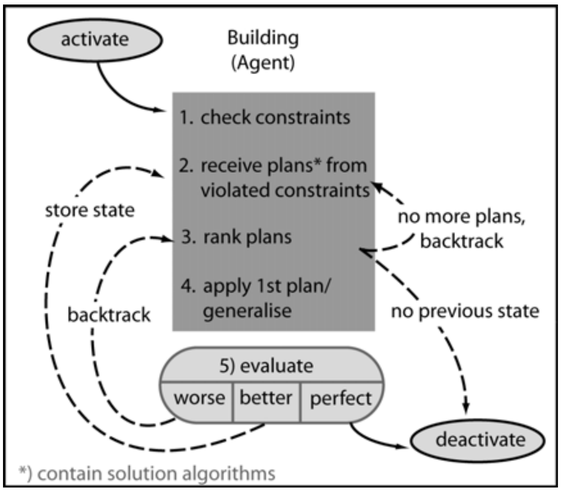

Figure 2: Generalisation procedure for a building (after Barrault et al. 2001).

A question still left open is how we can know that a constraint is fulfilled or not. Every condition is expressed as a measure that returns a quantitative value for a geometric or topologic property of one or more map objects. This value is transformed into a qualitative statement, the so-called *satisfaction*, by comparing them to a reference value, e.g. the minimum building size.

3. Introduction of Contextual Expert Rules

Our objective is to transfer the cartographic expert knowledge into the domain of automatic building generalisation. This can be done for instance when we try to extract higher order semantic concepts from the data which are not directly accessible but can be made explicit by pattern recognition techniques. A condition for the extraction of such higher order semantic concepts is that they represent a cartographically useful concept. In our case this includes on the one hand that the concept(s) can be related to cartographic map generalisation rules, while on the other hand the concept must be intuitive to understand for the average map reader. Based on the analysis of the generalisation literature (e.g. SSC 2005), such useful concepts have been identified by us with respect to the urban fabric. More specifically we identified a cartographically useful classification of buildings into five urban structure classes, including (1) inner city buildings, (2) industrial and commercial buildings, (3) urban buildings, (4) suburban buildings and (5) rural buildings. The pattern recognition method, here a supervised classification approach, is described in Steiniger et al. (accepted) and Steiniger (2006). The rules that should improve the generalisation of a 1:25,000 topographic map are given in table 2. They focus on two issues. First, they are aimed to reduce the number of generalisation actions/trials needed to obtain a satisfactory solution (characterised by a high happiness value of the building agent) and second, the cartographic quality should improve. Only Rules for the constraints C1-C3 are addressed. Rules for the constraints C4 and C7 are not established, since either only one or none solution algorithm is proposed. The other constraints (C5, C6, C8, C9) were not applied in the experiment.

constraints	urban context rules				
	Industry and business	Inner city	urban	suburban	Rural
minimum size (C1)	---	* retain space by higher ranking of *Elimination* * don't propose *Enlarge To Rectangle*	---	prefer *Enlarge To Rectangle* over *Polygon Scale*	* don't propose *Eliminate* * prefer *Enlarge To Rectangle* over *Polygon Scale*
Granularity (C2)	don't propose *Simplify To Rectangle*	don't propose *Simplify To Rectangle*	---	---	Prefer *Simplify* over *Rectangle to Simplify*
Squareness (C3)	don't propose *Squaring*	Don't propose *Squaring*	---	---	---

Table 2. Expert rules accounting for the urban context classes.

4. Experiment and Results

For the experimental part we used two datasets. The first dataset contains building data from the Region of Zurich, Switzerland with a resolution corresponding to 1:10,000 map scale (fig. 3). The second dataset contains the Region of Orthez in France and has been extracted from the IGN BDTopo database. For the generalisation of the buildings we used the commercial map generalisation system "Clarity" by *1Spatial*. For the reference generalisation we used expert settings similar to the one from the *Carte de Base* project

(Lecordix et al., 2006). In our experiments we only considered the constraints C1, C2, C3, C4 and C7 to more easily detect and evaluate knock-on conflicts.

Figure 3 shows the generalisation results for a part of the Zurich data. It can be observed that the cartographic quality increased. To evaluate whether the efficiency of computation increases when rules are applied, we created some statistics for the generalisation process. For the Zurich data we obtained a time reduction by about 15% for the expert rules and for the Orthez dataset a non significant reduction in processing time (approx. 1 %).

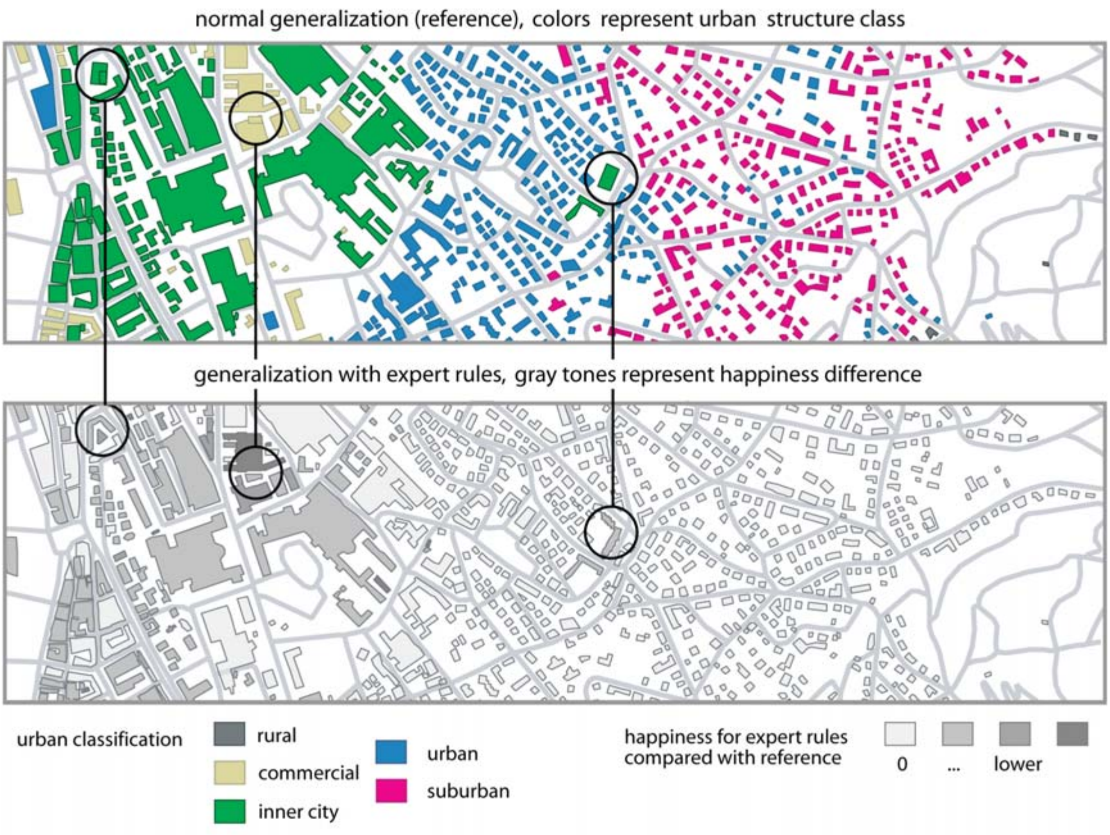

Figure 3. Comparison of the generalisation without and with expert rules for Zurich data.

5. Discussion and Conclusions

From the results presented we can clearly establish an improvement of the building generalisation as an effect of the rules that were introduced. During the experiments we also discovered problems in the ability to formalise the cartographic requirements in terms of graphical quality. More exactly, in the statistics we discovered a decrease of the average building happiness after the generalisation, although the results of fig. 3 (bottom) are *visually* more appealing. Therefore we see clearly a need for future research to define shape constraints and parameter settings to ensure that the buildings' happiness values express the quality experienced visually by the map reader. In our experiments we only considered constraints for a single building due to the target scale of 1:25,000. Thus, a next test should consider larger changes in scale, e.g. from 1:25,000 to 1:50,000. Here, we see even more potential of influencing the selection and control of generalisation algorithms based on the urban context classes, since more topographic detail needs to be reduced and hence, more contextual generalisation operations will become necessary.

6. Acknowledgements

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