CARTOGRAPHIC GENERALIZATION AND AGENT TECHNOLOGY FOR ROAD DATA

F.Gülgen and T.Gökgöz

- *degrees, name, family name;* Ms.Fatih Gulgen
- *work place;* Yildiz Technical University, Department of Geodetic and Photogrammetric Engineering, Division of Cartography
- *address for contact;* Barbaros Bulvari 34349 Yildiz - Istanbul
- *telephone, fax number, e-mail;* +90 212 259 70 70 – 2515, +90 212 259 67 62, fgulgen@yildiz.edu.tr

- *degrees, name, family name;* PhD.Turkay Gokgoz
- *work place;* Yildiz Technical University, Department of Geodetic and Photogrammetric Engineering, Division of Cartography
- *address for contact;* Barbaros Bulvari 34349 Yildiz - Istanbul
- *telephone, fax number, e-mail;* +90 212 259 70 70 – 2353, +90 212 259 67 62, gokgoz@yildiz.edu.tr

Abstract

Generalization is the task of producing multiple maps, of a different scale or purpose, from a single detailed data source. The field of generalization can be split into model generalization and cartographic generalization. In model generalization, the objective is to reduce the resolution of the data by decreasing the number of features, without changing the shapes of the remaining features. On the other hand, cartographic generalization involves displaying the geographical features required for a map's purpose or scale, while removing irrelevant detail that would clutter and confuse. In cartographic generalization, the symbols for features occupy a greater fraction of the space available giving rise to increasing spatial conflict. These conflicts are resolved by simplifying, distorting or exaggerating various aspects of the data. Improvements in computing power over the last few years have allowed greater automation of this task. Early attempts at automatic generalization involved a GIS or digital mapping software application applying geometric algorithms, one at a time, to modify individual map features. Today, generalization involves software agents. These are individual map features, activated as self-aware entities, which generalize themselves in order to improve their cartographic appearance. In this paper, agent technology is examined from the cartographic generalization perspective for the road data at the scale 1:25 000, using the 1Spatial's advanced system, Radius Clarity, for automated generalization.

INTRODUCTION

In cartography generalization is the process of deriving from a detailed source spatial database a map or database the contents and complexity of which are reduced, while retaining the major semantic and structural characteristics of the source data appropriate to a required purpose. It represents a process of informed extraction and emphasis of the essential while suppressing the unimportant, maintaining logical and unambiguous relations between map objects, maintaining legibility of the map image, and preserving accuracy as far as possible (Weibel and Jones, 1998). Transition from the manual techniques to automated generalization is difficult and complex. In a manual environment, generalization could often be achieved with a single stroke of the pen, through activities such as selection, collapse, smoothing, and displacement, despite each procedure needs to be addressed individually in automated generalization (Richardson and Mackaness, 1999).

In digital cartography and GIS automated generalization is seperated two main branches, model generalization and cartographic generalization. (Weibel and Jones, 1998; Richardson and Mackaness, 1999; Weibel and Dutton, 1999; Jiang and Claramunt, 2004; Neuffer, et al, 2004; 1Spatial, 2007).

Model generalization concentrates on the derivation of reduced databases from source databases (Weibel and Jones, 1998). The objective in model generalization is to reduce the resolution of the data by decreasing the number of features, without changing the shapes of the remaining features. As the geometry is not modified in the process, model

generalization is often used in situations where aesthetics are less important than accuracy, such as with aeronautical charts or when the size of data storage is an issue (1Spatial, 2007).

Cartographic generalization represents the process of deriving a graphic product or visualization from a source database (Weibel and Jones, 1998). It is constraint-based process used by cartographers (Jiang and Claramunt, 2004), and involves displaying the geographical features required for a map's purpose or scale, while removing irrelevant detail that would clutter and confuse (1Spatial, 2007). Cartographic generalization has to deal with the specific problems of graphical symbology. The printable area of a reduced scale map is smaller. At the same time, the relative size of map symbols becomes larger, leading to a competition for scarce space among the map features, inducing processes such as displacement (to avoid symbol overlaps) or aggregation of map features. The primary aim is for the resulting map to convey a clearly readable image (and hence a clearly decodable message) which is aesthetically pleasing. In cartographic generalization clarity and logical consistency of graphic expression is given priority over positional accuracy and completeness (Weibel and Jones, 1998).

Improvements in computing power over the last few years have allowed greater automation of this task. Scientists have benefited from Object-Oriented (OO) paradigm (Ruas, 1998; Ormsby and Mackaness, 1999) and agent-based systems (Lamy, et al., 1999; Barrault, et al., 2001; Duchene, et al., 2001; Duchene, 2004) to solve generalization problem. OO provides fundamental design capability and high performance in spatial applications with large volumes of complex data. Besides, agents in agent-based systems are all about managing complexity and a fundamentally new way of considering complex distributed systems, containing societies of autonomous cooperating components (Lamy, et al, 1999).

In 1997 the European Community decided to support an agent-based generalization project called AGENT (Automated GEneralisation New Technology) during three years. The project was built on 1Spatial (former Laser-Scan)'s OO – GIS software LAMPS2. The products of this project triggered some National Mapping Agencies (NMAs) such as IGNF (Institut Géographique National France), KMS (Danish Kort & MatrikelStyrelsen), IGNB (Belgium Institut Géographique National) and OS (Ordnance Survey Great Britain) to move their generalization studies to a new platform with a project called MAGNET (Mapping Agencies Generalization NETwork) in 2002. The new generation platform dedicated to generalization was the first version of Radius Clarity which is 1Spatial's advanced generalization system (Lecordnix, et al, 2005).

Radius Clarity is based on an OO database called Gothic. This provides powerful object processing capability and also the platform for agent-based generalization. It provides the generalization facilities for building production flow lines and for research and development of algorithms and processes. It enables you to derive digital data at different scales from large scale source datasets. It uses sophisticated algorithms, constraints and processes to achieve generalized results that are of high cartographic quality (1Spatial, 2007). Radius Clarity has also been used in generalization studies presented in this paper for road network.

AGENT-BASED SYSTEM

An agent is an object that will control itself in order to improve its cartographic appearance. An agent can be described by a set of rules or characteristics, known as constraints. These are used to evaluate an agent, to propose algorithms to apply to an agent and to decide whether the agent has improved or not (1Spatial, 2007).

There are two levels of agents (Figure 1a) in Radius Clarity (1Spatial, 2007):

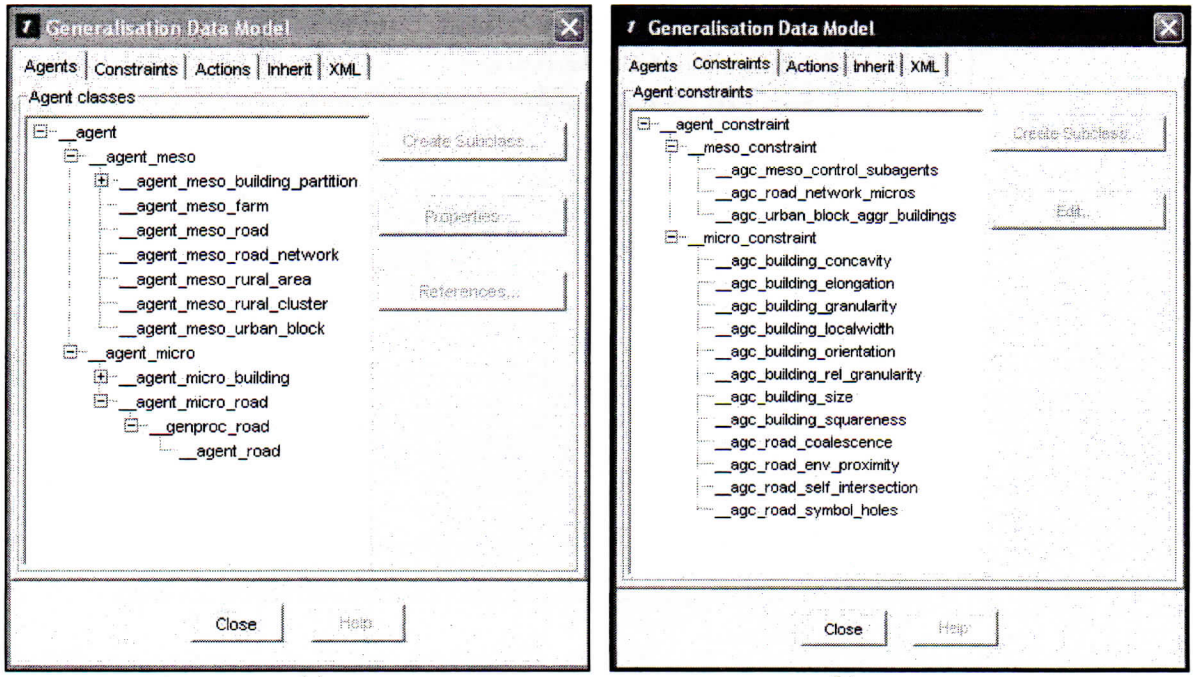
- *Micro-Agent:* A micro-agent is an individual feature which controls itself, for example, a road, a building etc.
- *Meso-Agent:* A meso-agent is usually a temporary object which controls and co-ordinates the activity of a group of features, for example, a network of roads or an block of buildings in an urban area.

The other important core of the system is constraints. Each of them normally controls one characteristic of an agent and its particular class, for example the squareness of a building. Each agent has a set of constraints to guide its generalization (1Spatial, 2007). Micro and meso levels are also valid for constraints.

There are three types of constraints (Figure 1b) in Radius Clarity (1Spatial, 2007):

- *Monitoring:* A monitoring constraint assesses the progress of the agent.

- *Proposing:* A proposing constraint is used to compute the overall happiness of the agent and also to propose plans to improve its happiness if the current state of the agent is not satisfactory.
- *Evaluating:* An evaluating constraint is also used when computing the overall happiness of the agent.



(a) *(b)*

Figure 1. Agents (a) and constraints (b).

The Agent Lifecycle

The agent lifecycle enables an agent to select and apply to itself those algorithms that produce the optimal compromise between the goals set by its constraints (Figure2). When an agent enters the lifecycle, it examines how far it is from satisfying each of its constraints, and then uses the constraint weightings to determine its overall level of happiness. If the overall happiness is good enough the lifecycle terminates, otherwise it continues (1Spatial, 2007).

Map Specification

A map specification is the component containing the information and parameters for the target map. There is usually one map specification object for each target scale (Figure 3). The map specification specifies the constraints to be associated with the specific agent classes, and the global and class-specific parameters for the algorithms (or more specifically the actions) and the constraints (1Spatial, 2007).

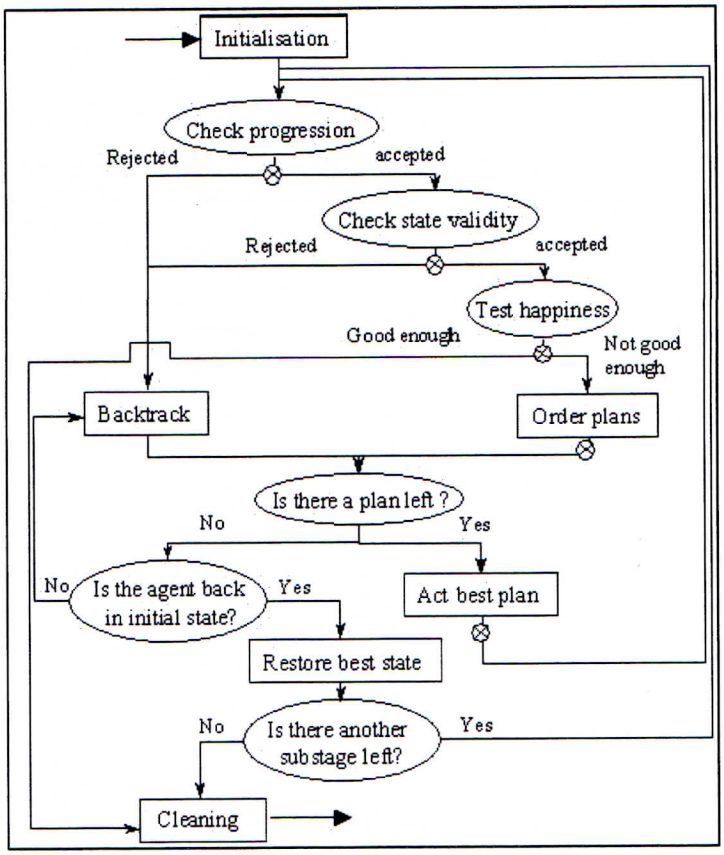


Figure 2. Agent lifecycle (1Spatial, 2007).

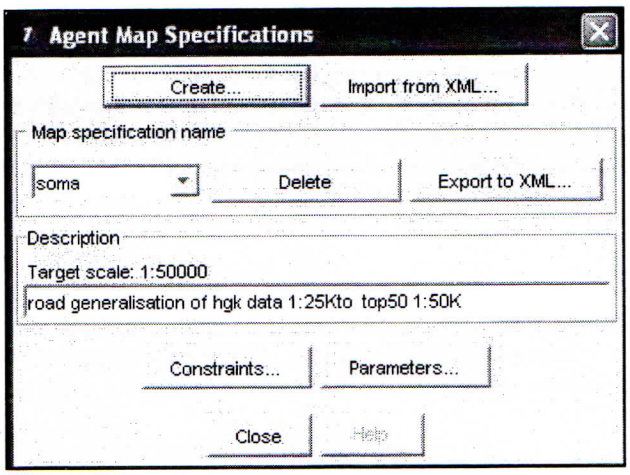


Figure 3. Map specification.

Agent-based System for Road Data

When generalizing a road network, both independent and contextual generalizations are to be dealt with. Independent generalization of roads aims to solve legibility conflicts occurring inside one single road feature. Contextual generalization aims to solve conflicts between road features (e.g. over-density of roads, overlapping between roads) (Duchene, et al, 2001). According to this idea, micro level should deal with independent generalization, and meso level should deal with contextual generalization in agent system. In micro level, two main kinds of symbolization conflicts can occur inside a road: coalescence conflicts, when the symbol of the road overlaps itself, and granularity conflicts, when the line is too detailed for the displayed scale (Figure 4) (Duchene, et al, 2001).

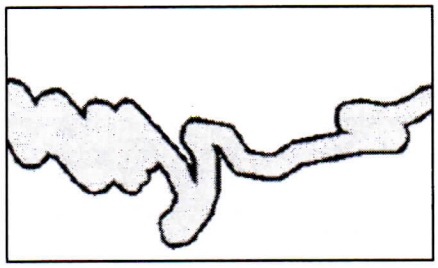
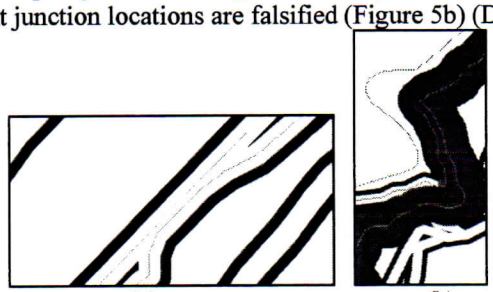


Figure 4. Legibility conflicts inside a road (1Spatial, 2007).

In meso level, increasing road symbols creates overlaps between close road sections (Figure 5a) which mislead to wrong topological relations. It also hampers junction configuration analysis since it conceals the smallest road sections. Angles between roads and event right junction locations are falsified (Figure 5b) (Duchene, et al, 2001).



(a) *(b)*

Figure 5. Road symbol overlaps (a), and road junction conflict (b) (Duchene, et al, 2001).

In this study, Radius Clarity and its road generalization algorithms are examined from the independent generalization perspective for the road data at the scale 1:25 000. The eight algorithms used in agent system are Figure 6.

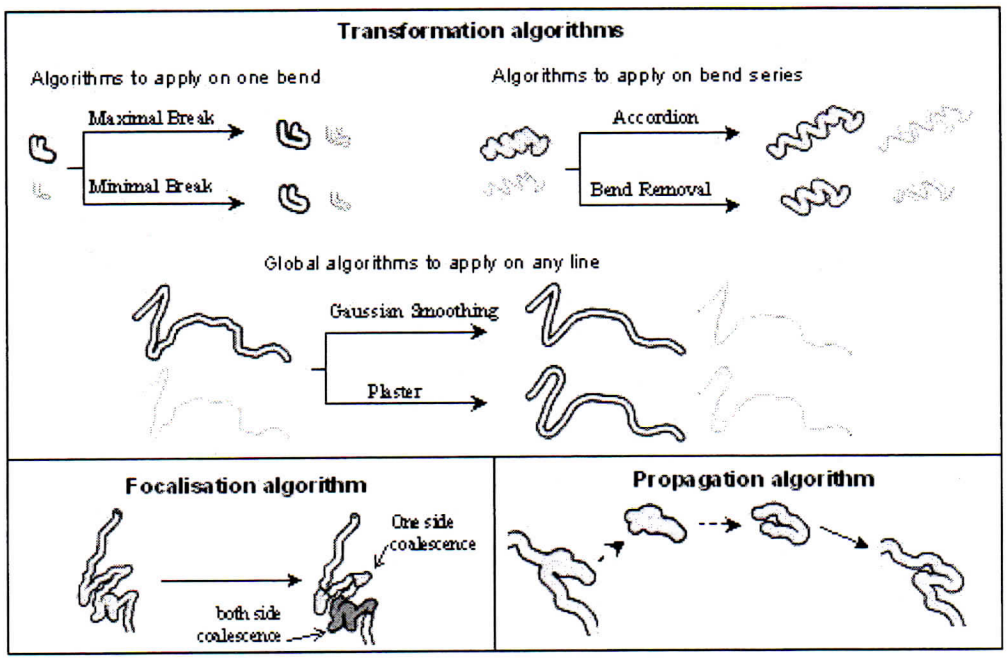


Figure 6. Road generalization algorithms available in the AGENT prototype and Radius Clarity (Duchene, et al, 2001).

CASE STUDY

Radius Clarity uses an application data model to describe how the road data is represented on map for generalization. It describes the source data model specifications which define each feature type in a separate class. In our application data model, six types of road data and three types of railway data are described in separate classes (Figure 7).

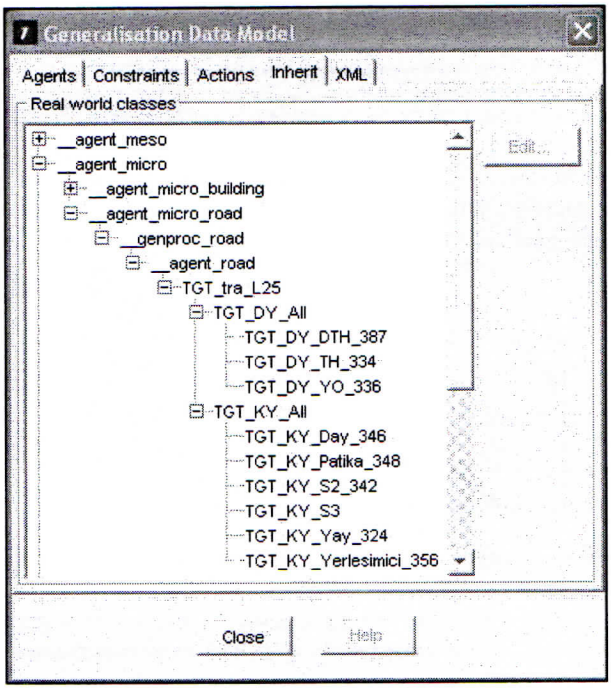


Figure 7. Application data model classes.

Figure 8a shows the imported road data in Gothic database after roads translated to the proper classes, and then 8b shows the map after setting up the symbol parameters such as road width an colors according to the Turkish General Command of Mapping's symbology at scale 1:25 000.



(a) (b)

Figure 8. Road data in database (a), and map.

If the symbol widths are exaggerated to the scale 1:50 000, the map is presented as in Figure 9. In this situation, legibility conflicts are appeared (Figure 10).

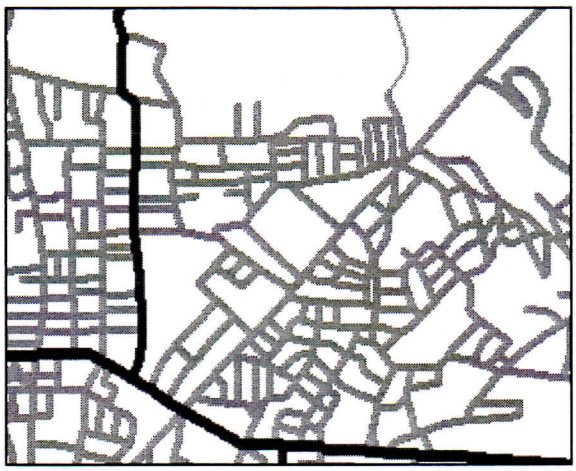


Figure 9. Exaggerated symbol width.

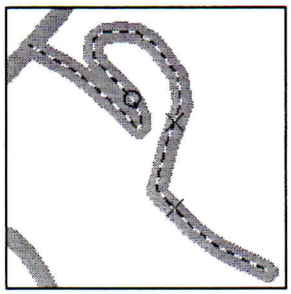
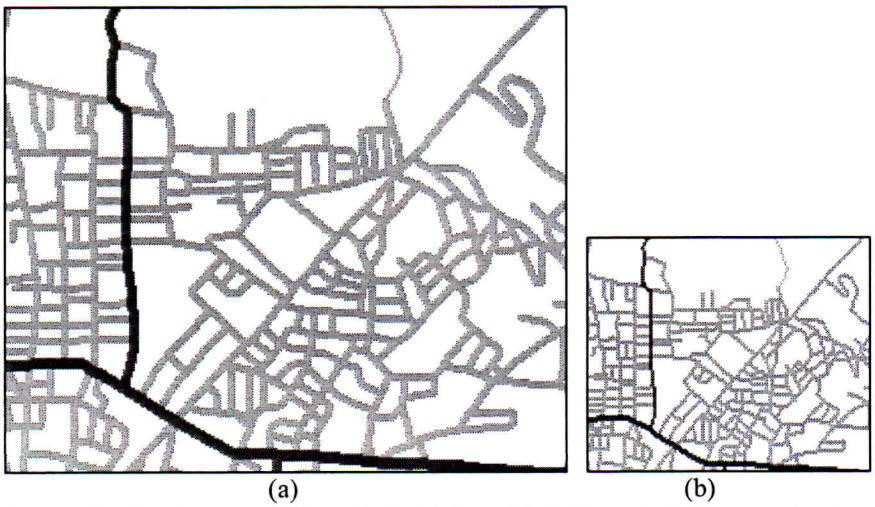


Figure 10. Coalescence in a road.

Figure 11a and b show the results after agent-based generalization technology applied to the roads to improve their visibility.



(a) (b)

Figure 11. Road data at scale 1:25000 (a), and 1:50000 (b) after generalization.

CONCLUSION

The study shows that agent-based system is considerably effective for independent road generalization. Cartographically, legibility conflicts for individual roads are disappeared when the constraint parameters are selected properly from the map specification component. On the other hand, the main problem is appeared in road network generalization when the big scale change (i.e. from 1:25 000 to 1:100 000) is occurred. In this situation, some road classes or individual roads should be removed from the map preserving main road pattern structures.

REFERENCES

Spatial, (2007), "Concepts in Clarity", Issue 1.3 for Clarity V2-6, 1Spatial Group Limited, Cambridge, United Kingdom.

Barrault, M., Regnauld, N., Duchene, C., Haire, K., Baeijs, C., Demazeau, Y., Hardy, P., Mackaness, W., Ruas, A., and Weibel, R., (2001), "Integrating Multi-agent, Object-oriented, and Algorithmic Techniques for Improved Automated Map Generalization",. Proc. 20th Intl Cartographic Conference, Beijing, 2210-2216.

Duchene, C., Barrault, M., and Haire, K., (2001), "Road Network Generalization: A Multi-Agent System Approach", Proc. of the 20th International Cartographic Conference, vol.3, Beijing, 2001, pp.2166-2177.

Duchene, C., (2004), "Generalisation Cartographique Par Agents Communicants: Le Modele Cartacom", PhD. Thessis, Universite Paris.

Jiang, B., and Claramunt, C., (2004), "A Structural Approach to the Model Generalization of an Urban Street Network", GeoInformatica, Vol. 8 Issue 2, pp157-172.

Lamy, S., Ruas, A., Demazeau, Y., Jackson, M., Mackaness, W.A., and Weibel, R., (1999). "The Application of Agents in Automated Map Generalisation", Proc. of 19th International Cartographic Conference, Ottawa., 1999, vol.2, pp.1225-1234.

Lecordix, F., Regnauld, N., Meyer, M., and Fechir, A., (2005), "MAGNET Consortium", 8th ICA WORKSHOP on Generalisation and Multiple Representation, A Coruna, July 7-8th, 2005.

Neuffer, D., Bell, M., and Woodsford, P., (2004), "Cartographic Generalisation on the Basis of Model Generalisation", Symposium Praktische Kartographie Königslutter, 17th - 19th May 2004.

Ormsby, D., and Mackaness, W., (1999), "The Development of Phenomenological Generalization within an Object-oriented Paradigm", Cartography and Geographic Information Science, 26(1), pp. 70-80.

Richardson, D.E., and Mackaness, W.A., (1999), "Computational Processes for Map Generalization", Cartography and Geographic Information Science, 26(1), pp. 3-5.

Ruas, A., (1998), "A method for building displacement in automated map generalisation", International Journal of Geographical Information Science, Vol. 12 Issue: 8, pp789-803.

Weibel, R., and Dutton, G., (1999), "Generalizing Spatial Data and Dealing with Multiple Representations", In: Longley, P, Goodchild, M.F., Maguire, D.J. and Rhind, D.W. (eds.). Geographical Information Systems: Principles, Techniques, Management and Applications, Second Edition. Cambridge, GeoInformation International, pp.125-155.

Weibel, R., and Jones, C. B., (1998), "Computational Perspectives on Map Generalization", GeoInformatica, Vol. 2 Issue 4, 307–315.