Project Number	**ESPRIT / LTR /24 939**
Project Title	**AGENT**
Deliverable Type	**Report**

Deliverable Number	**D M7**
Internal ID	***AG-01-01***
Contractual Date of Delivery	**30/11/2000**
Actual Date of Delivery	**01/02/2001**
Version	**1.0**
Workpackage/Task contributing	**Contact / Annex II / Article 10**
Authors	**UNI-ED, INPG, LSL, UNI-ZH, IGN**
Confidentiality	**Public**

Title of Deliverable	**Technological Implementation Plan**

Abstract

This implementation plan summarises the foreground (i.e. the advances) from the different points of view of the communities associated with this project. It describes:

- the advance in the geographical information sciences, which can be typified as a new model to generalise the information to be represented on a map.
- the achievements, progress and perspectives in multi-agent systems and the contribution of AGENT to research and knowledge in the domain.

It presents the exploitation intentions commercial perspectives in the short term:

- expected commercial exploitation in the software market,
- expected production exploitation in the mapping industry.

It summarises the actions of the partners of AGENT to promote their acheivements.

Keyword List

Exploitation, Generalisation, Commercialisation, MAS, Geographical information

0. Executive Summary

Foreground

On the research level, the modelling of cartographic processes of AGENT is recognised as innovative in the geographical information (GI) community. The main breakthrough are an effective usage of the notions of autonomy and constraints, as well as of different levels of analysis. These notions were effectively evaluated by the research teams during the project.

From the multi-agent system (MAS) point of view, it is worth emphasising the value of using recursion and heterogeneity in searching among candidate solutions.

From the commercial point of view, the use of the multi-agent technology has allowed the user and the commercial partners to overcome several limitations in their currents products and processes.

Promotion of the use of generic technology

The MAS of AGENT is one of the deepest and most thorough developments of MAS for GI. The commercial partners, both software designer and mapping agency, have stressed the importance of quality in the prototype, as well as the involvement of the research teams in the implementation. It is regarded a milestone in the effective use of MAS in spatial analysis.

Exploitation intentions

These largely positive results have encouraged the commercial partners (a SME and a user) to involve their development departments with the following objectives:

- Laser-Scan aims to produce a commercial product based on the results of AGENT, and to bring it to market in 2001.
- IGN aims to use the results for the production of the map series at the scale of 1:100 000. The production will start in 2002.

Authors

Yves Demazeau (INPG)
Paul Hardy (Laser-Scan Ltd)
Yolène Jahard (IGN)
William A Mackaness (University of Edinburgh)
Serge Motet (IGN)
Robert Weibel (University of Zurich)

Table of Content

1. Introduction

In the Annex II "General Conditions" of the "Cost Reimbursement" Contract of the project ESPRIT / LTR / 24 939 AGENT, article 10 says:

> Contractors shall, through the Coordinator, also submit at, or before, the end of the Project a technology implementation plan acceptable to the Commission. This plan shall indicate all potential Foreground Rights and exploitation intentions (including a timetable) taking account of Community policies, including those for the transfer of technology to SMEs, and promoting the use of generic technology

This report aims to fulfil the obligations of the partners regarding these terms.

Because the exploitation and the transfer of technology was parts of the work-plan, several reports released during the project, deal with different aspects of the implementation and its planning. Besides, several papers have been published on the scientific achievements of the project. Therefore this technology implementation plan *includes previously published materials* by the partners of AGENT, mainly in the deliverable DM.5 "Future Exploitation" and during the ACI workshop on 1999.

2. Foreground in GIScience

Chapter written by Robert Weibel, University of Zurich & Anne Ruas, IGN

2.1. Generalisation as a Fundamental Problem of GI

Scale is one of the major factors in the study and explanation of spatially related phenomena. All spatial sciences know the scale problem. In meteorology and climate research, for instance, Global Circulation Models (GCMs) are used to model and predict air mass circulation at the global to continental scale, while other models are used to explain circulation at the regional (meso) or local (micro) level. Similarly, in the study of land surface forms (geomorphology), the phenomena studied range from the glacial erosion of the Canadian Shield (continental scale) to the marks carved by a rain drop hitting on sand (extreme micro scale). For each of these scale levels, different measurement techniques are needed, different data, and different models. And since scale is so important in the study of spatial phenomena, methods for *scale changing* are also indispensable; otherwise, how could the findings of different scale levels be integrated?

Due to the overwhelming importance of scale and scale changing, it is not surprising that research into methods for dealing with scale is a top priority. The University Consortium for Geographic Information Science (UCGIS, the association of academic GIScience labs in the USA) has made scale problems one of ten top priorities on its research agenda (UCGIS 1996). The topic also consistently features prominently on the technical programs of GI Science-related conferences.

Cartography has always had the task of visualising spatially related phenomena. Hence, it is itself exposed to the problem of appropriately handling scale, a problem which is aggravated by the fact that visualisation necessarily takes place on a drawing medium of restricted size. In cartography, the problem of scale reduction is termed ***generalisation***. It encompasses a reduction of the complexity in a map (or database), emphasising the essential while suppressing the unimportant, maintaining logical and unambiguous relations between map objects, and preserving aesthetic quality.

In geographical information system (**GIS**), generalisation functions are needed for a variety of purposes, including the creation and maintenance of spatial databases at multiple scales, cartographic visualization at variable scales, and data reduction, to name just a few. Figure 1 visualises these multiple roles of generalisation. Generalisation occurs in three different forms along the path from the real-world phenomenon to its representation in a digital model or on a display medium, respectively:

- as part of building a primary model of the real world (a so-called digital landscape model = DLM) — also known as *object generalisation*
- as part of the derivation of special-purpose secondary models (DLM') of reduced contents and/or resolution from the primary model — also known as *model generalisation*
- as part of the derivation of cartographic visualisations (digital cartographic models = DCM) from either primary or secondary models — commonly known as *cartographic generalisation.*

Of these, model generalisation and cartographic generalisation are particularly interesting, as they relate to derivative products, assuming that a source database (primary model) exists. It is important to note that the main difference between the two forms of generalisation is that model generalisation is a non-graphical process where aesthetics do not matter, whereas cartographic generalisation is governed by the rules of graphical legibility and clarity. Model generalisation can be equated with controlled data reduction (e.g., for the purpose of reducing the volume of a data set while minimizing the loss of accuracy in a statistical sense); this process has not existed before the advent of the digital age. On the other hand, cartographic generalisation -- even in the digital world -- still follows the same rules as in conventional cartography, though the user requirements may be different today.

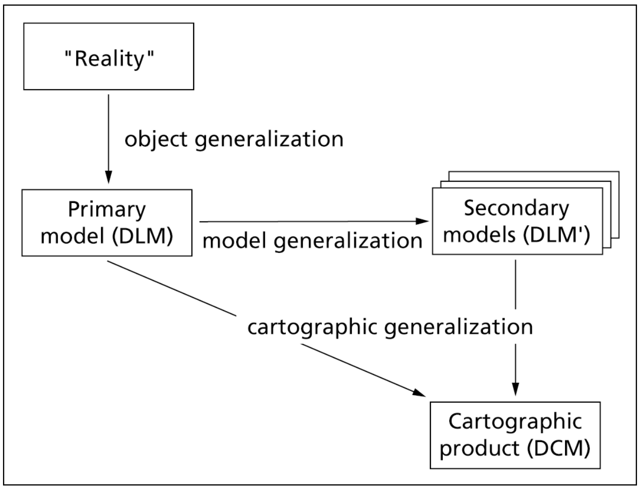

Figure 1: The different types of generalisation, and the link between model and cartographic generalisation.

The AGENT project has exclusively addressed the automation of **cartographic** generalisation. It is generally acknowledged that cartographic generalisation is a complex process with ill-defined objectives, involving a good deal of subjective decisions. Hence, the use of AI-related techniques such as multi-agent systems, in combination with algorithmic methods, was thought to hold considerable potential.

The scientific foreground of AGENT is a **new model** to generalise the information to be represented on a map. The model is based on:

- autonomy, constraints and
- the representation of different levels of analysis.

The model is summarised in the notion of **life-cycle**.

2.2. Autonomy and Constraints

In AGENT model implemented in the prototype, Generalisation is performed step by step, in an autonomous way. A geographical entity is autonomous in as much as it chooses an operation which satisfies its own constraints. The final state aims at finding a compromise between constraints which incite generalisation and those which ensure a preservation of geographical meaning. In this model, constraints represent the users needs on each situation. Each instantiated constraint is qualified by a level of non satisfaction - or severity - which changes during the process.

All of these principles need the conception of specific mechanisms for decision making, control and communication. The Figure 2 shows the different steps used by one situation to generalise itself. Details of each function is given in [Ruas 98].

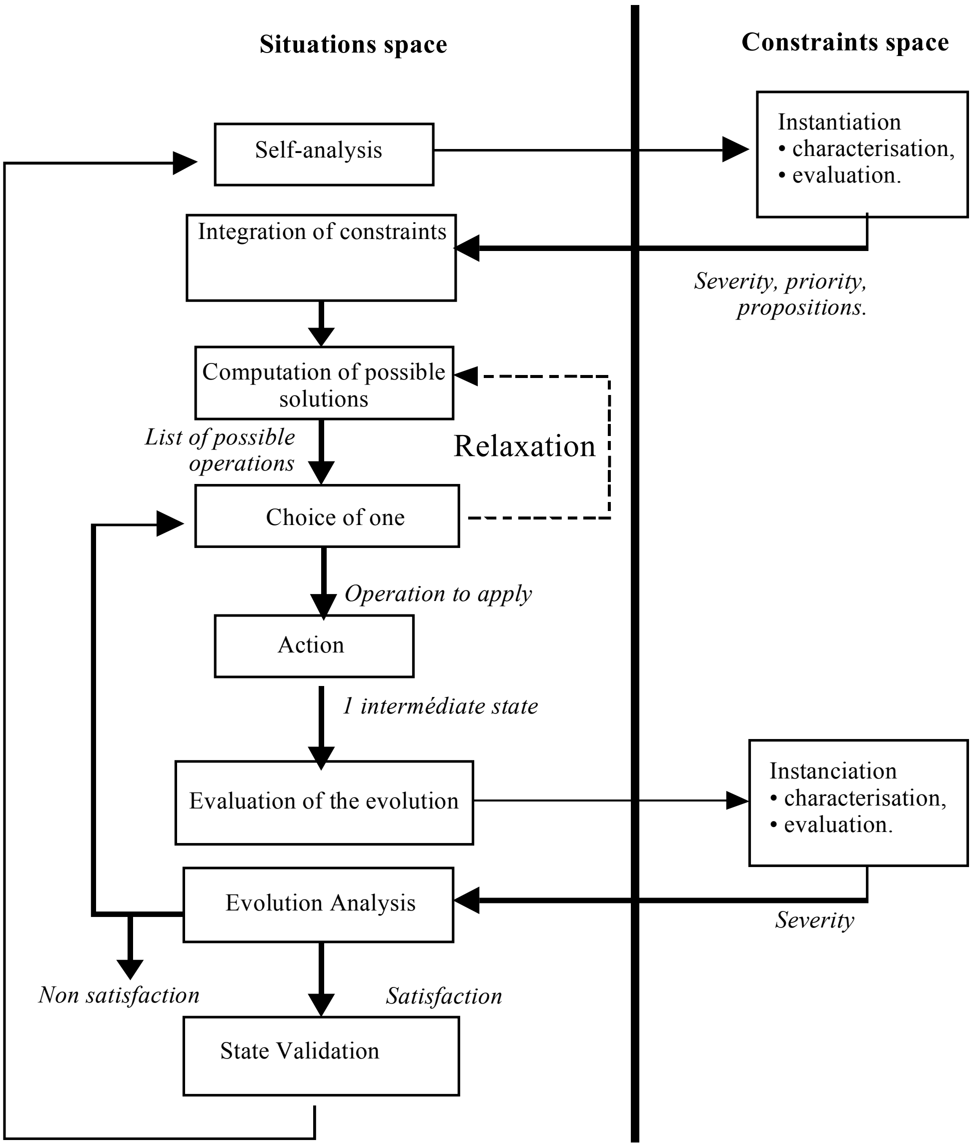

Figure 2

2.3. Different Levels of Analysis

In order to preserve groups properties and to apply contextual operations (e.g. object removal or displacement), we introduce the concept of *meso* situations which are groups of objects that either generalise themselves together or analyse their properties to provide finer guideline for simple object self generalisation.

Among such analysis we emphasise on distribution analyses either to ensure dissociation between values or to maintain exceptional values within a group. Actually, generalisation at the lowest level (i.e. independent) has the tendency to remove differences between characters which in term destroys geographic space specificity

More precisely, The levels are:

- **Micro level**: the level which contains objects one by one, as they are loaded at the beginning of the process.
- **Meso level**: the level which contains groups of objects. These groups are created during generalisation process to allow contextual operations and to maintain some group properties. A meso object is composed of a group of micro objects or a group of meso objects.
- **Macro level**: the level which contains population of objects. One macro object is all road, another one is all houses. Macro objects are necessary to control quantity evolution.

Micro, meso and macro objects do not perform the same role during the generalisation process, but all are constrained :

- Micro objects generalise themselves when they are autonomous or accomplish orders given by meso objects for contextual operations,
- Meso objects generalise themselves when they perform contextual operations. They also give information to their component objects in order to maintain some group properties.
- Macro objects give information to meso and micro objects to control quantity evolution.

2.4. Agents'Life-Cycle

As a consequence of the model described above, Agents can be viewed as **active** when they act autonomously and chose the way to generalise by themselves or **reactive** when they are ordered by an upper-layer meso-agent. In the first case, agents have a number of methods in order to implement them as autonomously acting entities generalising themselves and their map environment. Alternatively they can obey orders to execute plans given to them by organisations.

In an autonomous state, an agent aims at reaching its own goals that means to satisfy a set of constraints : its current happiness will therefore depend on the current degree of satisfaction of its constraints. Constraint can be of different types: graphic, topological, structural, or Gestalt [Weibel, 98]. They can act at different levels: micro (minimum size), meso (proximity), or macro (global density). The flexibility of the system will be given by changing the goals of the agents from new map specification *(if scale decreases, minimal size has to increase*).

Constraints must be supported by specific measures (one or several) to be characterised.

2.5. Promotion of the Use of New Methods

If AGENT is put back in the context of the research in GI Science, it is first worth noting that generalisation still receives a lot of interest today. It is still one of the topics most represented at international GI Science conferences and in scientific journals. During the past years, the research community has produced a continuous stream of results, and techniques have matured. It is interesting to note that many of the methods used and put forward by AGENT are now also used by other groups: Contextual data models (Delaunay, Voronoi) and object-orientation are now commonplace; the study and use of constraint-based methods is wide-spread; and some groups are even starting to use MAS. As a result, we see the appearance of better generalisation methods in the literature. We also see the use of new computational techniques borrowed from other fields, primarily numerical optimization techniques which are used for placement and displacement problems, such as least-squares adjustment, finite element methods, snakes (or active splines), and simulated annealing. In all of these areas, AGENT and related research carried out in the consortium groups have had a profound effect on the research community, thanks to the combined thrust of five research groups, which enabled us to integrate formerly dispersed ideas and methods.

3. Foreground in MAS Research

Chapter written by Yves Demazeau (INPG)

Concerning the discipline of MAS, the contribution of AGENT can be summarized in three main achievements, all of them related to the methodological aspects of MAS:

- At the Analysis level, is the **modelling** of cartographic processes within a MAS paradigm.
- At the Design level, is the use of **recursion** and **heterogeneity** in searching among candidate solutions.
- At the Application level, is new directions for MAS in real applications such as **hybrid MAS** and **new applications** of the results of AGENT.

3.1. MAS Analysis

The a priori choice of a recursive approach (see also section 3.2.) imposes a static and dynamic analysis problem. Up to which level is it still advantageous to continue to decompose the problem into finer and finer cartographic elements? How to find a optimal initial decomposition for an application and what are the criteria for that?

From the VOWELS (A E I O, standing for Agents, Environments, Interactions, Organisations) Analysis including the decomposition algorithm, three possible approaches were possible to solve the cartographic generalisation problem (listed below)

1. The Procedural approach: a pure Extrinsic Spatial approach where A are the procedures or algorithms and have the power for solving the generalisation problem. E corresponds to the objects the procedures act upon. I is limited to negotiation to determine who becomes active to take an action on an object. O is used for finding the sequencing between the processes.
2. The Constraints approach: a pure Intrinsic Temporal approach. The constraints are the active entities and thus the agents A. E corresponds to the objects the constraints are responsible for. I is limited to negotiation to who tries to fulfil the constraints. O is used for ordering the constraints and has the power for solving the generalisation problem.
3. The Phenomenological approach: a combination of intrinsic and extrinsic decomposition, flexible to the types of geographical information that is handled at a given time. A are the geographical information, E corresponds to the geographical database or space. I is the generalisation algorithms. O is used as a control structure. A and I have the power for solving the generalisation problem.

The last approach was chosen because it was the 'closest fit' with respect to a geographical point of view and given our current knowledge of generalisation and the qualities that define an object oriented approach to GI problem solving. From a MAS point of view, any of the three approaches would have been possible. An important contribution from the MAS point of view here, was the systematic listing by the VOWELS of the possible approaches. The research has given fresh impetus to the INPG methodology and has helped to define it more precisely.

3.2. MAS Design

3.2.1. Recursion

Considering an agent as a MAS introduces several problems (a meso-agent can be seen as a MAS on its own). The AGENT project has motivated some more formal work on recursive structures in MAS. A basic approach for a generic recursive MAS has been developed.

The implementation of the recursive society is carried out in two steps: the search for an initial decomposition (see also previous section) and the development of the recursive dynamics. As the environment decomposition is imposed by the context, the dynamic behaviour of the recursive mechanism aims therefore to choose dynamically the best level of processing.

Recursion on A induces a complexity reduction of the design effort (due to compositional aspects) even if the problem is not recursive. Recursion on E allows to design quite naturally the structure of knowledge in multi-scale or partitioning problems. MAS can take diverse advantages of building recursively I according to the characteristics (recursive or not) of agents and environment.

The recursive approach is also interesting because it reduces the processing time. However, as we decompose, the decomposition time becomes gradually significant, which can lower the method's advantages. Results show that there exists a depth on which the recursive approach is not more attractive than the traditional approach.

The approach was illustrated on several other examples in addition to the AGENT project. From the analysis of the results, we can observe the three main MAS improvements by the recursive approach as they were expected : design complexity, representation efficiency and system performance.

3.2.2. Heterogeneity

The several reactive (more data directed) and cognitive (more goal directed) entities have been designed in the AGENT project according to very different considerations, also due to the state of the art of cartographic generalisation. The two approaches usually present heterogeneous characteristics from both knowledge or behavioural point of views. At a more theoretical level, this heterogeneity constitutes a particularly difficult problem when these two kinds of MAS have to cooperate as is it the case in the AGENT project. In AGENT, the goal is to control the evolution of the more reactive MAS (the micro level) by the cognitive MAS (the meso levels) in order to carry out an integration of the goal-driven and data-driven reasoning so that we can consider it has been solved for the application, even if it was done in some ad hoc manner. But to deal with this problem in general, some theoretical interaction models for heterogeneous MAS involving observation and emergence techniques are now studied at INPG. Unfortunately, this generic issue and the corresponding results to come were not well foreseen at the beginning of the project, and the final prototype will not take full benefit of further research.

3.3. Application Level

3.3.1. Hybrid Multi-Agent Systems

As direct exploitation of AGENT, from a MAS perspective, the project has contributed (see also section 3.2.2) to the development of a new research direction: hybrid MAS to model complex systems. Some complex systems indeed imply several decision-making systems that work with spatialised intelligent systems. Such systems can be encountered in several domains where the decision process is based on spatialised pre-processed data or where the decision making guides the spatialised data processing. This is for example the case for robotics control (decision and vision or map processing), for submarine or flight control (decision and radar or sonar signal map processing), and also for GIS (decision and cartographic data processing). Such applications involve large amounts of knowledge as well as tasks that are heterogeneous both in terms of their nature and their granularity. They both need data-driven and goal-driven problem solving techniques at different levels. On the one hand, cognitive MAS are well suited to model cognitive systems involving complex agents able to reason on both environment and representation of others agents to reach their goal. On the other hand, reactive MAS efficiently model problems where the environment data guide the solution. The problem occurs when tackling applications in which some permanent interaction and control between these two kinds of systems are required. For resolution systems, the goal is to control the evolution of the reactive MAS by the cognitive MAS in order to carry out an integration of the goal-driven and data-driven reasoning. This is the case in the AGENT project. In the case of simulation systems INPG is also investigating, the problem is tackled in an opposite direction, it is the evolution of reactive MAS that will guide the cognitive MAS.

3.3.2. New Applications of the Results of AGENT

As indirect exploitation of AGENT, one could think about several research topics developed in MAS research institutes like INPG. After the initial work on robotics agents, telecommunication agents and software agents, the current activity is mainly about interface agents and internet agents, and it is very difficult to predict which application domain agents will investigate next. From a MAS perspective, the focus has been initially given on Closed MAS, then on Open MAS, and finally on MAS involving Human Agents. We believe that the next kind of MAS to be considered will derive from the unavoidable merging of the real world and the virtual world, where artificial agents and human agents will live together. Future INPG research will work in this perspective, and it is hoped that some of the achievements made through the AGENT project will have impact on future research on Organisations (Hybrid Systems), Methodologies

(VOWELS), Multi-Agent Oriented Programming (Domains and Problems), and Benchmarks (dedicated to MAS).

4. Commercialisation

Chapter written by Paul Hardy, Chief Product Manager, Laser-Scan Ltd & Robert Weibel, University of Zurich

The research results of the project are embodied as prototype functionality in Laser-Scan's Gothic LAMPS2 products. However, the results are not yet engineered to commercial standards and do not cover the full range of necessary functionality. This report section overviews the prospects for commercialisation of the project results into sellable standard software products, and the work required to achieve this.

4.1. Laser-Scan as Commercial Partner

This part gives background information about the commercial partner (Laser-Scan) including recent changes in ownership and the product range into which the new functionality fits.

4.1.1. Laser-Scan Ltd

Laser-Scan is a British company, based in Cambridge. It was founded in 1969 and it has been involved in digital mapping since 1975. It had £8m turnover in 1999. It has 100 staff in the UK HQ and 25 in USA Office. After 30 years of independence, it was taken over by the Yeoman Group in 2000.

Laser-Scan has a wide customer base, particularly of National Mapping agencies (NMAs). Its main strengths are its spatial object database and toolkit, its Mapping & Geodata production software, and in Web and Mobile mapping.

4.1.2. Yeoman Group PLC

Yeoman Group is a fast moving British public company, strong in electronic positioning. The company structure is shown in the figure 3.

Yeoman target markets include location based services, delivery of intelligent mapping for web and mobile phone, geospatial aspects of content databases, generation of driving instructions, and bespoke generalised maps on-demand, as exemplified in the web sites http://www.CamMap.com/ and http://www.knowheremaps.com/.

4.1.3. Effects of Yeoman on Laser-Scan

The effects are positive, as Yeoman brings in a financial boost, a vision and drive, and a market focus. The stated focus for Laser-Scan under Yeoman is to continue with the National Mapping Agency and large commercial mapping production customers, but expand into server-side support for web and mobile solutions. Generalisation is therefore still an important element in the strategy.

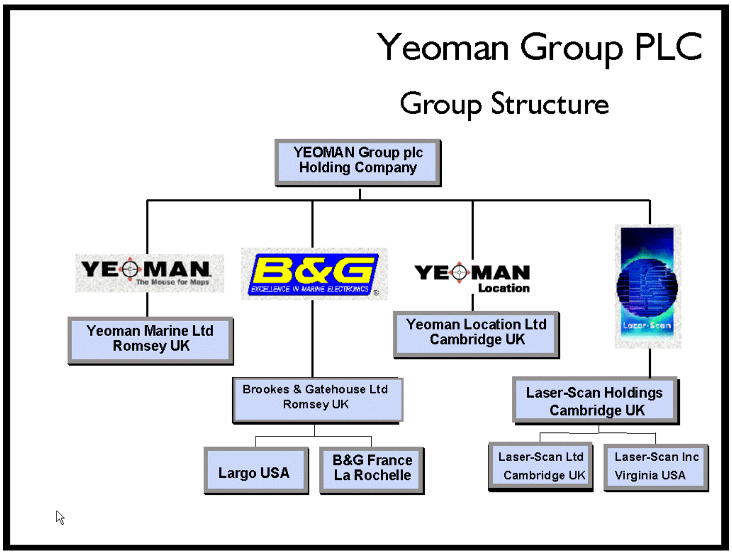

Figure 3

4.2. Gothic Products

4.2.1. Gothic Family

Laser-Scan's primary products form the Gothic family, centred around the Gothic spatial object database. The primary product for map and geodata production is LAMPS2, which was used as the platform for the AGENT project research, the P1 prototype and the demonstrator. A second relevant product is the Gothic Integrator: Java Edition (GI:JE) toolkit, used for building web solutions such as the P2 prototype.

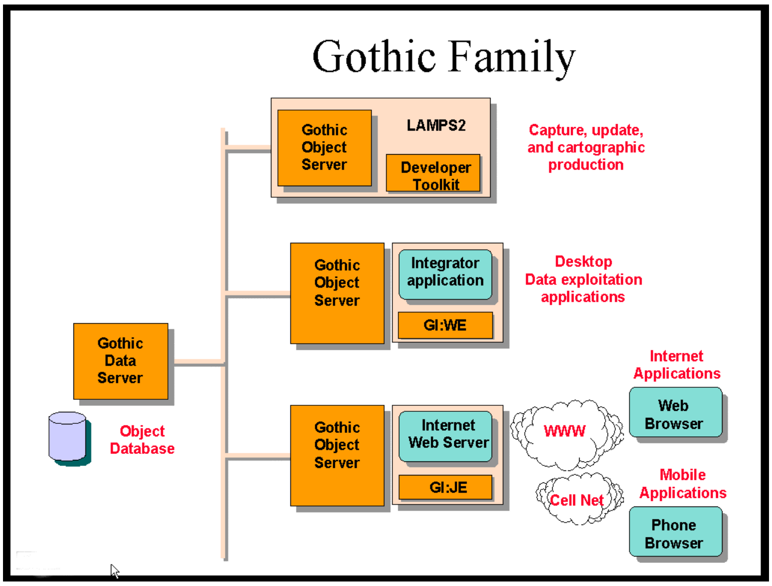

Figure 4

4.2.2. Gothic - Key Aspects

The Gothic architecture provides three major advantage areas to support AGENT:

- **Object database** – provides efficient storage, a versatile Schema (data model of real world), and continuous mapping (no sheet edges)
- **Spatial database & toolkit** – provides answers to questions about 'where', using a Quadtree spatial index for rapid access, and support for topological structure (adjacent, connects).
- **Active objects** – objects are not passive, but have methods & behaviours. These provide active representation for good cartography, and Process methods (e.g. for generalisation).

4.3. Commercial systems before AGENT

In 1995, two studies involving two GIS products with cartographic generalisation capability were carried out at the University of Zurich. One of the projects involved the extension of a general-purpose GIS (ESRI's ArcInfo, Version 6.2) to build a prototype with interactive generalisation functionality, using macro extensions and C code (Schlegel and Weibel 1995). The second study (Weibel and Ehrliholzer 1995a,b) was sponsored by Intergraph, Inc. and involved an evaluation of their MGE MapGeneralizer product, a software module that was specifically designed for interactive cartographic generalisation. Most of the general findings that surfaced from the two studies were the same and can be summarised as follows:

- Many generalization algorithms were still missing: Lots of line (simplification) algorithms, very few polygon or point pattern algorithms
- Unspecific algorithms, not specifically designed for particular feature classes (e.g., no algorithms for *road* caricature, *building* outline simplification, etc.). As a result, the same algorithms (e.g., line simplification) had to be used on features that were of completely different nature.
- The systems merely offered an interactive toolbox, lacking procedural knowledge and suggested workflows and/or defaults. Consequence: The user was overburdened with parameter tweaking and twisting.
- No ‚orchestration' of the various operators and algorithms.
- No built-in evaluation and little help for the user in his/her visual evaluation process.
- Layer-based systems: No topological and/or semantic relationships between feature classes possible
- Lack of integration of databases
- No WYSIWYG symbolization. For instance, instead of displaying roads with the correct symbol width as double lined bands, they could simply be displayed as single lines, which made it impossible to evaluate displacement effects or the amount of simplification needed.

These findings were clearly supported by a further study carried out by a working group of the OEEPE (European Organisation for Experimental Photogrammetry) and summarised in Ruas (1998). Those experiments also included a third package (CHANGE by the University of Hannover), a series of batch programs restricted to generalisation at large scales (roughly 1:5 000 to 1:25 000).

4.4. LAMPS2 Generaliser Option

4.4.1. LAMPS2 Current Facilities for Generalisation

In 1997, Laser-Scan added a purpose-built generalisation capability to LAMPS2. It has been used in South Africa for O-O Generalisation from 1:50K => 1:250K. However since then, the development has paused while AGENT evolves. The Generaliser option provides:

- A set of basic generalisation algorithms (Aggregation, Classification, Clustering, Collapsing, Displacement, Exaggeration, Refinement, Simplification, Typification).
- A framework for applying an algorithm to a set of map features (process methods)
- A process sequencing framework to carry out a batch of processes
- A visual interface with slider bars to setting tolerances

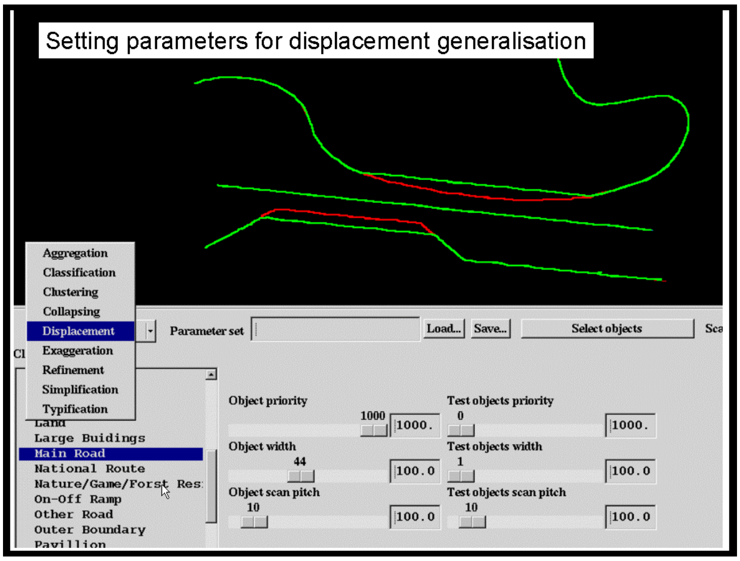

Figure 5

Besides, LAMPS2 has various facilities for generalisation, even before the AGENT project

- interactive edit
- process methods
- topology
- LAMPS2 Generaliser option

4.4.2. Weakness and Strengths of the Current Facilities

Weaknesses	Strengths
- Feature at a time processing - no group context - Algorithms limited (LSL not experts on cartographic theory)	+ Distribute knowledge onto object model + Good framework for batch processing + Versatile, wide-ranging capability (not tied to

- Same algorithm applied to all features - Not marketed much (because AGENT would change things) - Not easy to modify (fixed interface)	specific classes)

Table 1

It should be seen as a complement to the AGENT capabilities, rather than being totally replaced by them. A full solution will require a blend of AGENT, Generaliser, and interactive completion.

4.5. AGENT Generalisation

4.5.1. Scope of Project

The study stage of the project covered many feature classes, but the Prototype concentrated just on two: Buildings and Roads. These were chosen because they are hard, important to humans, and as one area and one line type, they are representative of other feature classes.

The AGENT methodology has two main advances:

- Micro agents try different algorithms, keeping results if makes better, discarding and trying different if worse.
- Meso agents act as agents themselves, using algorithms that work on groups of objects. They also coordinate generalisation across sets of micro agents, so as to avoid conflicts, and retain overall consistency

4.5.2. AGENT Project Contributions

The project has contributed several ways towards a commercial product. In particular, it provided prototype implementations of:

- Framework for active agents (lifecycle)
- Set of generalisation algorithms
- Measures and Constraints (make choices)
- Map specification (limited)

In addition, it also has provided

- Reports on best practice
- Sample datasets and results
- Experience!
- Established links between Laser-Scan and the academic partners

4.6. Market for Generalisation

4.6.1. Generalisation Customers

The initial market for generalisation is the European National Mapping Agencies (NMAs), and is hence small. The eventual market is significant, as on-demand mapping and web access to geospatial data becomes much the norm, but this will take time (several years) to ramp up.

Within the NMA market, sales first have to displace incumbent suppliers: primarily ESRI and Intergraph.

4.6.2. Already Customers

- Kort & Matrikelstyrelsen (Denmark) – doing 1:10K to 1:50K generalisation for paper map production. KMS did a competitive benchmarked of Laser-Scan, ESRI and Intergraph late in 1999, and chose LSL.
- IGN France – as well as being a major player in the AGENT project itself, IGN want to use the AGENT technology in various projects, notably the Carto2001 project to generate 1:100K mapping from BDCarto data. It has bought LAMPS2 licences including Generaliser for this (See chapter 5 Production) .

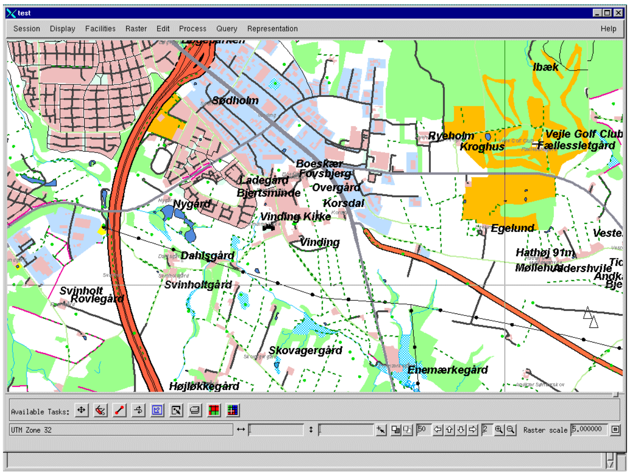

Figure 6

4.6.3. Strong Prospects

There are several prospects for short-term sales of generalisation software embodying AGENT capabilities. Commercial confidentiality restricts access, but a NMA is the most likely next customer and with the mapping agencies of a European states and of a European region being also active contacts.

4.7. What next?

Although the AGENT project has pushed forward the frontier for automated generalisation, there remains a substantial amount to do to commercialise the results of the AGENT project.

4.7.1. To Do

- Turn Research into Engineering
  - Robustify, remove bugs, memory leaks, etc
  - Add user interface for production operation
  - Add user interface for setting up specifications
  - Add user documentation
  - Performance improvements (some algorithms are currently very inefficient)
  - Refine behaviours and parameters for constraints, algorithms, measures
- Retain an audit trail through the processing stages
- Handle 3D data
- Extend to other classes beyond buildings and roads
- Create sales collateral (brochures, white papers, demos)
- Create training course, and train support group.

4.7.2. Next Steps

The next steps in commercialisation are:

- Productise what we have now, quickly over next three months, to allow urgent deployment.
- Continue with the engineering and documenting
- Consider the feedback from customers such as IGN and KMS who have been using the Agent systems
- Develop functionality to suit current customers (KMS, IGN)
- Merge AGENT prototype with existing Generaliser to make a Mark 2 LAMPS2 Generaliser
- Make available in Gothic Integrator architecture as well as Developer (LAMPS2)
- Market and sell product !
- Follow-on cooperation with partners to continue the advances in generalisation.

5. Production

Chapter written by Yolène Jahard (Project Carto 2001/IGN) and Serge Motet (Research Dept. IGN)

This chapter introduces the exploitation of the results of AGENT in the short and long term.

IGN-F is commissioned to capture and manage the French national geographical data bases. Annual budget amounts over 100M Euro, half of this provided by the French state and half comes from commercial returns. Staff amounts to 1800 people including 350 Engineers. It is located in Paris and other 17 agencies.

The activities of IGN aim at building, maintaining and distributing core geographic information over the national territory. These products aim at meeting a large range of usage.

5.1. IGN Products

The products of IGN are of two kinds:

- maps or graphical products,
- products containing GI (geographical information), i.e. explicit description or structured inventory of the reality (See http://www.ign.fr/fr/MP/BDGeo).

The partition is based on the content. At present, the media of delivery are also different (paper for the first and CD-ROM for the second) but this difference is meaningless, since maps can also be delivered on CD-ROM or another digital medium (web). The partition is formally not so sharp. But as far as usage and segment of marketing is concerned, it is relevant and well established.

5.2. Trends and Directions in Production

The results of AGENT come under the general issues of the production and the efficiency of the processes which build maps and GI. They will change these processes in numerous products.

This part introduces the trends of the production. The following parts present the consequences on the processes and then how AGENT will help to answer on the long term. The last part is more specific. It introduces the project "Carto 2001" which already starts, based on the results of AGENT.

5.2.1. New Medium

In the imminent future, the best known change is the change of medium. With the progress of the information society, it is likely that the products will be delivered on CD rather than on paper and then, when the bandwidth of the network will allow this, on the web rather than on CD. New services will certainly emerge, this will imply a greater demand. But, as far as production is concerned, the consequences are limited. It is mostly a question of hardware for delivering the outputs of products.

5.2.2. Durability of Products

A more important point is that the products (GI or maps) will keep the same specifications on short and medium term.

One reason is that the peculiarity of usage of maps will not change. The principles of cartography are still valid. Maps have been designed to avoid confusion and not overwhelmed the reader by details. And this objective will of course remain.

The other point is that the habits of consumers are strong, so strong that the new products try to keep the appearance of paper maps. For instance, the designers of MapPoint 2000 of Microsoft) have stressed that one key feature of the product is to look like "true" maps.

(See. http://www.microsoft.com/office/mappoint/default.htm)

The conformance is also required when a map supports a human-computer interface, i.e. when a map is a document of a multi-media product, were names and symbol are "hooks" to fetch other documents. The similarity with paper map is part of the paradigm.

For GI product, there are also technical reasons for the stability. It takes a lot of time and effort to the users to be aware of the present product specifications and to develop applications based on these specifications. The users will probably want products to last and be maintained in their present forms.

5.3. Map Production Processes

Based on these trends, there are two directions of development:

- The first one is obvious. All the processes of IGN should be completely digital. In these processes, the automatic batch processing should be preferred to interactive operations.
- There is a stability in the content of products. This allows to back the production with investments on the content.

These investments are the databases that IGN maintains. There are four databases (Because, at present and for the next decade, one cannot merged and derived by generalisation a too large range of scales):

- a database on altitude (digital terrain model),
- a database with an accuracy of 10 m (BD CARTO),
- a database with an accuracy 2 m, under completion,
- a database for car navigation.

The databases make up the **information system** of IGN. This information system remains for the internal use at IGN. It keeps a topographical description of France at different scales, based on contributions of local agencies, in close relationship with the local management.

The exploitation of AGENT at medium term is downstream from the information system. It will build the products from the information system. In particular, all national map series of IGN (1/25 000, 1/50 000, 1/100 000 and 1/250 000) should be produced from the information system.

The map-making process can be divided into two categories:

5.3.1. Renewal

It is the current process. For each version of the map, the data are extracted from the information system. It is laid out mostly interactively, with the help of a workstation, supplemented by some batch processes (like name placement). The process does not memorise specific information over time. Each version is a new product. The effort of production remains steady for each edition of the product.

5.3.2. Revision

It will be the future process, particularly of the national map series. It will go through two different steps:

1. The creation of an initial cartographic data-base. The process of creation will first use autonomous generalisation. It will be completed by a phase of interactive control and end on graphical workstations.
2. The maintenance. Only the changes will be extracted from the information system and the cartographic data-base will be revised (i.e. updated). It is expected to be largely automatic.

It is worth noting that, like the information system, the principle of revision is viable only if the cartographic specifications of the product remain the same or are close. The chapter 5.2 explains why this assumption is very likely.

The process for revisable products uses a derived cartographic data-base as an intermediate step. Thus, the initial effort for the first edition is slightly more important than a renewal, because the creation of the derived data-base needs more care and an enhanced structure.

But this process become very attractive and efficient for the following editions, which are produced at a very lower cost. Indeed the yearly rate of changes is between 2 to 10% depending on the location and the type of information. The cost of the maintenance will probably be reduced to a range between 10% to 20% of the cost of the renewal.

5.4. Long Term Perspectives

Before going further into the production of revisable maps, two perspectives for the results of AGENT should be mentioned on a longer term.

5.4.1. New GI Products

The first one in the derivation of GI products from the information system. At present, the GI product are selections made either at the semantic level (only some objects or some attributes are provided) or at the spatial level (only an area is provided), complemented with a simple topological clean up. IGN proposes two of these products —called ROUTE 500 and ROUTE 120— adapted to fleet management.

More complex derived product can be envisaged. The result of AGENT can be used to produce data sets adapted to specific need. The development of these customized GI products appears to be desirable but it is not certain. Because a new product needs a significant effort of marketing, a clear position in a range of products and, firstly, the development of applications.

5.4.2. Unified Information System

The second perspective is more certain but in a later stage. The result of AGENT will allow to reduce the number of databases in the information system, until it is reduced to a single "master" database. The principles are the same as maps: the generalised databases are considered as a revisable product. As explained before, there are 2 steps:

1. The (re-)creation of an initial generalised data-base. The problem is different for the cartographic process, because the generalised database already exists. Then, the problem is to link the features of the master and the generalised databases. There are 2 questions: which structure for the unified system and how to set up the links. On the structure, IGN studies a multi-representation system. This work comprises internal R&D and the participation to the European project MurMur (See http://lbdwww.epfl.ch/e/MurMur/).

   To answer the second question on populating the structure, IGN has been working for 4 years on designing matching software.
2. The revision. There are also two questions:
   - the propagation of the information on the evolution from the master to the generalised database and the maintenance of the multi-representation links,
   - the generalisation (as the process of map product, the revision will be largely automatic and will use the results of AGENT).

As a very long term perspective, one can envisage that the products will be renewed automatically.

5.5. Project "Carto 2001"

The project "Carto 2001" is an internal project of development at IGN. The team of this project was set up in July 1999, for a duration of 30 months. The staff is 4 permanent members.

5.5.1. Objective

The objective of the project is to build a process of text placement, generalisation and updating for the map series at the scale of 1:100 000, based on the results of the project AGENT and the research department of IGN.

The expected result is to produce the graphical file of a new map at a direct cost of around 5 k Euro by map, during the maintenance phase (Cf. 5.3.2). This implies a large usage of automation.

Among the components of the information system, the master database for the application is BD CARTO.

The software used by the project is:

- LAMPS 2 with the results of AGENT included by Laser-Scan and
- a internal software for name placement.

This report focuses on the specific contribution of the multi-agent systems. Nevertheless, it is worth noting that the effort of AGENT to include the results into a robust software is decisive in the success of the exploitation. One key advantage of this upgraded software is to gather algorithms which were developed by the research partners of the project on several platforms. They are now included in a commercial software.

The actual developments of the project "Carto 2001" will depend on the first commercial product of Laser-Scan, which includes results from AGENT. It is due to the next three or six months. But some of the technical directions can be described below.

The 1:100 000 is a revisable product. Then, as explained on 5.3.2, the project "Carto 2001" aims to design and to develop 2 processes, creation and maintenance, which are both going to use the results of AGENT.

5.5.2. Creation of the Cartographic Data-Base

5.5.2.1. Road Network

The road network is the most significant theme of the maps at 1:100 000 because these maps are intended to the drivers. The main contribution of AGENT is that the choice of the algorithm is autonomous, as the cutting of road sections. If this would be done manually, the duration and the cost of the creation will be increased to a rough estimate twofold.

The highest risk concerns the volume of data that can be processed. The best solution would be to derive the full database containing 1.6 million of edges but partitioning might be compulsory.

An important contribution of AGENT can be on the interchanges. Currently, the algorithms are not satisfying because they do not support all the configurations. The project Carto 2001 will test a multi agent implementation, based on AGENT framework. In this implementation, agents will be main road, bridge, access roads.

5.5.2.2. Rail Network

The probable solution will be to include railway as agents of road network, with a stricter constraint on the straightness of the geometry.

5.5.2.3. Hydrology

The geometry of river must not moved as it has to remain consistent with hill shading and contour lines The constraint is to keep coherent the road network and the hydrology (at the bridges, etc.). The drawing will probably be controlled by a mechanism of trigger or a very simple usage of MAS.

5.5.2.4. Punctual Symbols and Land Use

This information is a lot easier to treat. It will be drawn once the networks are generalized, probably with "old" methods of automatic cartography (displacement, dilatation).

5.5.3. Maintenance

On the maintenance, the project "Carto 2001" has worked mostly on the extraction of the change-only information.

On the revision, i.e. the generalisation of the changes and the integration into the existing map, the same order (road+rail, hydrology, punctual symbols and land use) is applicable. But comparing to the initial generalisation, texts are now part of the cartographic database and have to be taken into account when updating the geographical objects. The expected contribution of MAS is essential because of its capability of adaptation.

We shall use the capability of the MAS to allow the changes to analyse locally their environment and to adapt to this. The MAS has two advantages :

- The efficiency when a generalisation is triggered from few objects (in this case the changes). For instance, the extend of the displacement due to the inclusion of a new section of road is done locally, generally in the adjacent blocks. No thorough scanning of the map is necessary.
- The adaptability. The permanent and the changing features can be differentiated, the geometry of the master database can be included into the processing.

6. Dissemination

Results of AGENT as well as the AGENT prototype have been presented at various workshops.

An early version of the AGENT prototype (Version 1, restricted to independent micro agent generalisation) was demonstrated at the Third Workshop on Progress in Automated Map Generalisation, held on 12-14 August 1999 in Ottawa (http://www.geo.unizh.ch/ICA-bin/documents). This workshop was organised by the ICA Commission on Map Generalisation (which is chaired by Robert Weibel of the University of Zurich) and was part of a biennial series. Since the demonstration involved a very early version, the cartographic results (on building simplification) were far from perfect, yet the first-time demonstration of an agent-based prototype stirred substantial interest and workshop participants seemed to understand the great potential of agent-based approaches. At the same workshop, a paper presentation on parameter tuning for building simplification was given.

On 21-23 September 2000, the ICA Commission on Map Generalisation and the ICA Commission on Map Production held a three-day workshop in Barcelona on “On-demand Mapping” that was geared towards map production specialists (see http://www.geo.unizh.ch/ICA/Barcelona2000/). The workshop gathered close to 50 participants from national mapping agencies (NMA), private mapping houses, software vendors, and academic institutions. The workshop featured talks and live demonstrations from three software vendors (ESRI, Intergraph, and Laser-Scan) as well as from representatives of academic and NMA groups. The focus was on problems of production (and generalisation for) maps on demand, ranging from paper products to web maps and mobile GIS (e.g., WAP-enabled). AGENT was presented in a talk and demonstration by Anne Ruas of the IGN and Kelvin Haire of Laser-Scan, as well as in a talk on the Carto2000 project currently underway at the IGN (see chapter 3). Of particular interest was the possibility of a direct comparison between the products of Intergraph (DynaGen), ESRI (ArcInfo) and the AGENT prototype. Clearly, the AGENT prototype generated a lot of interest and the participants were impressed by the amount of functionality built into the software, not the least the representatives of Laser-Scan’s competitors.

Very recently, two workshops designed for specific NMAs were held. On 21-22 November 2000, the Danish national mapping agency KMS was hosted at the University of Zurich by the partners of the Universities of Edinburgh and Zurich, respectively. KMS is already a customer of LAMPS2/AGENT (cf. chapter 2). The main purpose of the meeting was therefore to explain in more detail the AGENT architecture, techniques, and algorithms; to give an in-depth demonstration of the latest version of the prototype; to discuss possible extensions; and to see how the prototype (or the future Laser-Scan product, respectively) could be best integrated into the existing workflows.

A second workshop was held the same week (on 23 November 2000) at Ordnance Survey of Great Britain (OSGB). This workshop was organised by Ordnance Survey but originally inspired by William Mackaness of the University of Edinburgh. It convened about a dozen of the UK researchers actively involved in generalisation research, plus Robert Weibel of the University of Zurich. The main goal of this workshop was to assess the current state of the art of R&D in generalisation and give recommendations to OSGB for their policy development. Once again, it appeared that the AGENT project and its prototype were seen as (probably) the most serious player. OSGB seems to be highly interested in the AGENT results (cf. chapter 2) and will meet with KMS in January 2001.

7. References

Richardson, D. and Mackaness, W.A. (1999, guest eds.). Special Issue on Computational Processes of Map Generalization. *Cartography and Geographic Information Science*, **26**(1).

Ruas, A. (1998). *Modèle de généralisation de données géographiques à base de contraintes et d'autonomie*. Thèse de doctorat, Université Marne-la-Vallée.

Schlegel, A. and Weibel, R. (1995). Extending a General-Purpose GIS for Computer-Assisted Generalization. *17th International Cartographic Conference,* Barcelona (E): 2211-2220.

UCGIS (1996). Research Priorities for Geographic Information Science. *Cartography and Geographic Information Systems*, 23(3): 115-127.

Weibel, R. (1995, guest ed.). Special Issue on Map Generalization. *Cartography and Geographic Information Systems*, **22**(4).

Weibel, R. and Ehrliholzer, R. (1995a). An Evaluation of MGE Map Generalizer. *Interim Report,* Project «Research in Support of MGE Map Generalizer», 36 pgs.

Weibel, R. and Ehrliholzer, R. (1995b). An Evaluation of MGE Map Generalizer. *Final Report,* Project «Research in Support of MGE Map Generalizer», 18 pgs.

Weibel, R. and Jones, C.B. (1998, guest eds.). Special Issue on Computational Perspectives on Map Generalization. *GeoInformatica*, **2**(4).