AGENT Project:
Automated Generalisation New Technology

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Introduction

Objectives of AGENT project

The purpose of AGENT is to produce an innovative map design software based on multi-agent technology . This comes at a time of increasing understanding in map generalisation, together with sophisticated software techniques for implementation. An important industrial consequence is that the autonomous design and display of maps according to themes and scales specific to the users' needs at multiple scales are within reach. More precisely, the project will achieve the definition and modelling of behaviours of "geographical agents and structures" in the context of generalisation. This includes mechanisms to select and to display agents, mechanisms to validate agents' actions, and the definition of strategies and dynamics that resolve competition among agents.
In order to validate the methodological research, the project will focus on two prototypes for the fully automated design of multi-scale thematic representations: a professional tool and a public information desk [Lamy,1998] .

Scope and structure of the paper

In this paper we present the main base-classes of our generalisation model, the way that they will interact, and the mapping with the actual Laser-Scan platform in response to the questions : "How is the agent paradigm used? How will the system work?"
The use of multi-agent system in the context of generalisation is first presented. The next part is devoted to the high level design of the global system with a description of the "geographical agents" and their life-cycle. Then, the convergence of the system is studied. Implementation work onto Laser-Scan Platform is presented in section 5. The last part presents the perspectives of work until the end of the project.

AGENT is part of the ESPRIT Long Term Research programme. It started on the 1st of December 1997 and will last three years. The partners are : Institut Géographique National (France), Laser-Scan Ltd (UK), Institut National Polytechnique de Grenoble (France), University of Edinburgh (UK), University of Zurich (Switzerland).

The use of muti-agent system to solve Map Generalisation

Map generalisation

Generalisation is the process that aims at simplifying geographical information to make it meet the users' needs, which means the enhancement of important information as well as the removal of unnecessary one. That simplification concerns entities (preservation, removal or grouping of objects) and their geometry (preservation or removal of geometric information such as location or shapes). [Lamy,1998] [Figure 1] shows three extracts of maps at different scales. By example, that Figure 1b and 1c could be derived from Figure 1a. This can be achieved by a mix of generalisation techniques (such as selection, merging, displacing, symbolising, simplification).

1:25 000 1: 100 000 1: 250 000

Figure 1 : Generalisation examples

Getting the right 'mix' of methods has revealed map design to be a complex spatial decision making process that operates at a number of design levels. Some operations occur at very local levels (micro level) whereas other operations such as displacement or selection are contextual and thus need to be applied to a set of geographical objects (meso level). The overall homogeneity of the map refers to an higher level (macro level)

We therefore require a framework that enables us to model design at various levels of granularity, from the map as a whole through to the fine detail. It is the absence of this framework that has stymied progress in autonomous systems and why existing systems typically require intensive interaction with the user [Lamy,1999].

Multi-Agent Systems for generalisation

The use of expert systems is limited by the near impossibility to develop a set of rules that would be large enough to foresee all situations that could occur, that could assess the competing rules, and provide coherent solutions.

Multi-Agent Systems (MAS) provides autonomy by enclosing knowledge in the agent structure, while ensuring global consistency. In a MAS, entities, called agents, interact with one another. Agents have individual capabilities, that turn them into autonomous agents aiming at solving a given problem. An agent has goals to reach and mechanisms to trigger in order to reach its goals. Agents can communicate, co-operate, co-ordinate, and negotiate with one another, to satisfy both their individual goals and the goals of the overall system. An agent goes continuously through a perception-reason-decision-action cycle until its goals are satisfied, which means that it has reached a stable equilibrium state [Demazeau 97].

For generalisation purpose we can define a set of agents whereby each agent is capable of performing a set of specific tasks pertinent to map design. The operations of each agent are being constrained by what is ‘acceptable design’. Acceptable design born from the idea of a ‘design policy’ at a number of conceptual levels, constraining/modifying the activities of the individual - defining what is acceptable. The agents work together, collectively, sharing in their successes and failures, the goal is a distributed set of activities that results in the construction of a map, having specified scale and theme.

Agents are not considered to be a utopia that obviates the need to tackle many of the problems identified by recent research in map generalisation. However they do offer a more transparent means by which we can model the complexities of map generalisation, in particular the often competing goals of map design and the complexities of grouping phenomenon in a meaningful way. [Lamy,1999].

Agents for generalisation

Micro and Meso agents

The phenomenological approach (geographical entities are agents) [Hangouet, 98] was given preference, being the most natural way to model generalisation through the MAS paradigm.

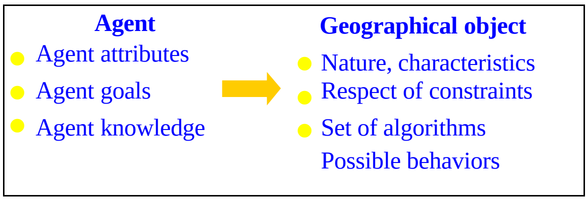

Figure 2 : Agent modelling

For instance, an object "Building" will be viewed in MAS as an micro-agent which has to respect its own constraints (as minimal size, and form preservation). If one or several constraints are not satisfied, it will have the capabilities to chose and trigger one of its behaviours (e.g. amplification).
But a building cannot decide to remove itself because of a too high density. Sometimes all particular goals (as minimal size) cannot be satisfied at the same time for a group of micro-agents, and an higher view is needed to guide the process.
In such cases, organisation (set of agents) will be used. The organisation can change its agents' goals, send them information, or give them orders *(a building can be ordered to be eliminated*) [Ruas, 99].
Such orders could be given only while organisations behaves as an agent, with its own goals to reach (*A goal for an organisation of buildings may be to reduce its density*), capabilities to trigger its behaviour.
As organisation concern an higher level than micro-agent, we call them in our model "meso-agent". In other words, organisations (or meso-agent) are structures which qualify the space and aim at guiding the process. They are responses to contextual operations and to the modelling of the generalisation strategies as well. Organisations give the framework that is required to model the different levels of abstraction (micro, meso and macro levels) as mentioned above.

Agents' life-cycle

Agents can become 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.

The examples of the next paragraphs are extracted from .[AGENT report, University of Edinburgh].

Let's take the constraints which could be applied to a building and a district for 1:50000 scale maps :

Building Constraints		**Building Goals**
Size constraint	Building should have a minimum size to be legible. This size depends on scale and symbol thresholds	Area: > 300m2
Granularity	the length of the edges constituting the boundary must not be less than a threshold, which itself depends on the specifications of the map.	Minimal_lengh_of edge > 20m
Accuracy constraint	The absolute position of a building should be preserved as much as possible.	Hausdorff distance: < 20m (from initial position)
District Constraints		**District goals**
Density	Density should not be too high	Density : <0,8

Figure 3: From constraints to goals

A violated constraint will be able to propose a set of behaviours to solve its violation (procedural knowledge in relation with constraints solving). *A violated constraint of granularity can for instance propose a simplification of a building to a rectangle or to a simplification with the preservation of some shape details*

An agent can therefore receive a list of possible actions coming from its set of constraints. As the behaviours that are proposed by one constraint can infer another violation of constraint (to increase size damages accuracy), agent must own decision capabilities to chose and trigger one behaviour. That choice is crucial and that procedural knowledge is encapsulated in the agent structure. It depends on a set of parameters such as the measure of how far the constraint goal is from being satisfied, the importance of the constraint from a more global cartographic perspective, or the degree of flexibility of the constraint. These parameters are related both to map specification and to the current state of the agent. The chosen action is triggered and the new state of the agent in respects to its constraints is re-evaluated. However the chosen solution can fail and another one can be tried through a backtracking process [Ruas, 1999].
The decision making is therefore a complex task and requires the capability to choose, to do, to evaluate and eventually to backtrack. The resulting mechanism is based on a mix of active perception of the local environment of the agent (through the use of constraints characterising the local agent context) and a decision function at a more cognitive level guiding the micro-agent's choice of the most appropriate generalisation algorithms. Such a mechanism is described in the following diagram:

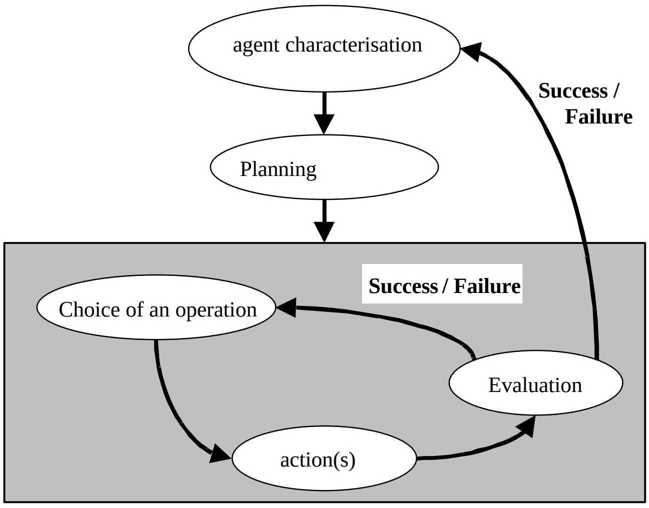

Figure 4: Life-cycle

Meso-agent will act at first in the same way as above described, like some « super » agent, meaning that it will analyse its current status through the use of spatial analysis operators (using e.g. Delaunay triangulation or Voronoi trees), in order to perform a first generalisation algorithm like removal or displacement of micro-agents with respect to its density,... This typically highlights the kind of operators realised at the meso level: every operation dealing with several micro-agents (or geographical objects) such as displacement, elimination or typification is treated at the meso level (using the micro-agents in their reactive substate) . Once the meso-agent reaches a satisfying state, it hands over control to its set of micro-agents, thus puts its micro-agents in the active substate. When all the micro-agents finish their « autonomous » local generalisation (given back control to the meso-agent), the representation of the set of micro-agents is updated at the meso-agent level [Ruas, 1999].

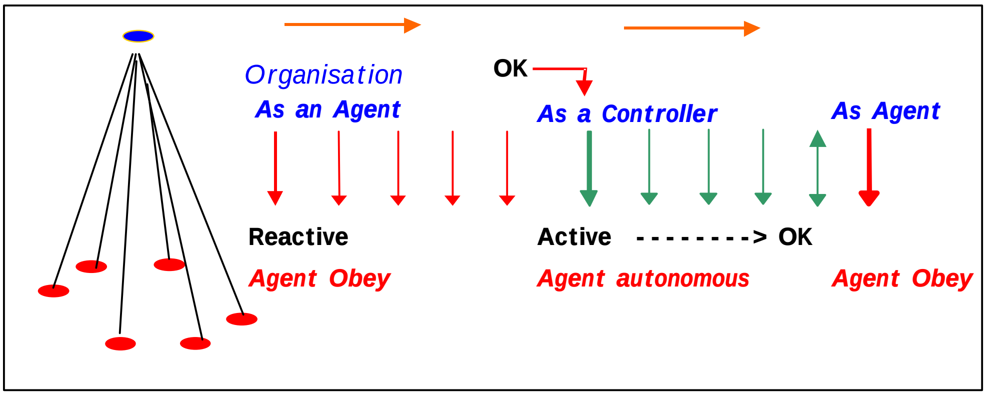

Figure 5:Active and reactive states

Some elements to ensure the system will converge

We have to integrate some mechanisms able to ensure that the system will converge to a solution (perhaps not towards an ideal solution, but in every case towards an "acceptable" solution one), or more surely mechanisms that will detect that the system cannot converge according to the current problem configuration or generalisation context. These convergence related elements are located at different levels in the proposed approach.
At the micro-agent level, two elements can guide to the conclusion that an agent cannot run infinitely :

- In its reactive state the micro-agent can be viewed as a slave (non-local decision making), a single imposed plan is executed, and the micro-agent is afterwards put in a final state with respect to its autonomy.
- In its active state, the activity of the micro-agent stops when the agent has reached a threshold of happiness (and not when it meets its ideal state). Moreover, micro-agent plans contain a finite number of generalisation algorithms to try. The control is sent back to the meso-agent at the higher level if the execution of all the algorithms of the plan does not lead to an improvement of its happiness.

At the meso-agent level, meso-agents are able to observe the set of agents they control. As no problem of termination of processes can occur at a micro-agent level, the unique remaining problem can be that a majority of micro-agents sends back a failure to reach a better happiness. In terms of agents this case can be solved,

- at the meso level locally, by giving reasoning capabilities to meso-agents to modify the micro-agent society (elimination, aggregation) until improvement of the solution is reached at a more global level, and by negotiation with other meso-agents
- at the macro-level by modifying the constraints criteria (quality of the solution ...) [AGENT report, INPG].

Use of Laser-Scan Technology in the Agent Project

Laser-Scan technology for MAS

Gothic is the name for Laser-Scan's state of the art spatial database technology. *Gothic* has many key technical features of which the most fundamental are that it is object-oriented, versioned, spatially indexed (dynamically), and topologically structured (dynamically). AGENT project will mainly use the two following applications that are built on on top of the *Gothic* technology: *LAMPS2* for map production, and *Integrator* for access to *Gothic* over the Internet / Intranet.
Object-Orientation in the context of Gothic's geospatial database has considerable overlaps with a Multi-Agent-Systems philosophy. A key concept of OO in Gothic, is that *functionality* is encapsulated with the *data itself*, making the transition between object and agent straightforward and relatively narrow. However, where OO and agent differ is that whilst an *object* has no choice but to execute its method in response to a message, an *agent* has the ability to negotiate **-** i.e. to communicate with the sender, perhaps executing its behaviour or perhaps not.
A key component of the transition between object-based and agent-based technology is the definition of an *interaction protocol* **-** a communication mechanism whereby rather than objects *instructing* each other, they *inform, persuade, advise, bargain, warn, order* etc. **-** i.e. they *interact* with one another as agents.
The proposed modelling has already begun being implemented onto Lamps2, using the pre-existing object-oriented technology [AGENT report, Laser-Scan].

Agent Demonstrators and Laser-Scan Technology

The Agent project requires two demonstrators. One demonstrator, namely P1 illustrates the use of multi-agent generalisation in a professional cartographic system for use by a national or commercial mapping agency, whilst P2 demonstrates contextual generalisation in an Internet environment. A different Laser-Scan application will be used as the basis for each demonstrator, with *LAMPS2* providing the platform for the professional cartographic system, and *Integrator Java Edition*, the platform for the Internet solution. Each application offers a different suite of tools aimed at specific sectors of the GIS market, and are each appropriate for the two Agent project demonstrators. Thus *LAMPS2* provides a variety of data modelling, capture, editing, and processing tools typical for map production, whilst *Integrator Java Edition*, compliments LAMPS2 with the necessary client and server tools for delivering such information over the Internet using Java and CORBA.

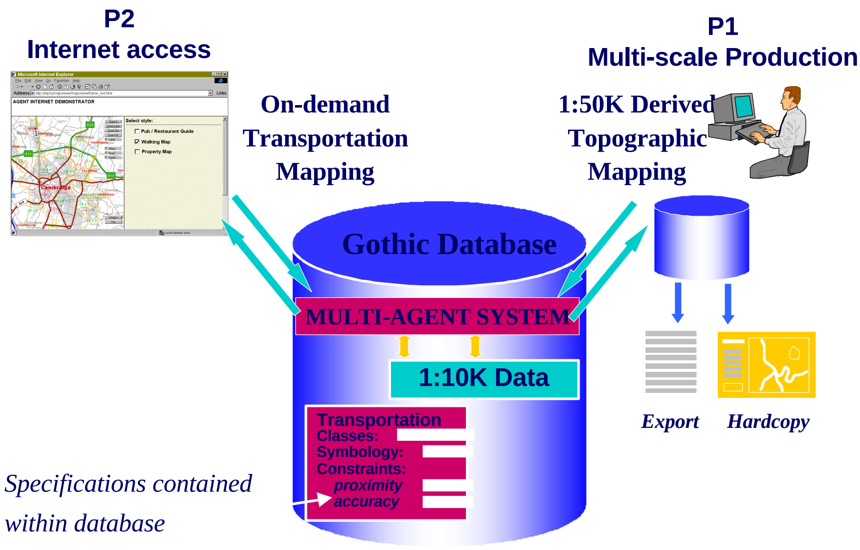

***Figure 6** : AGENT prototypes*

Perspectives

The use of agent methodologies, constraints, cartometric techniques for evaluation, has already being studied during the first year of the project. Micro-agent structure as well as micro-agent specific classes (buildings, roads) with their appropriate behaviours have been implemented. A contextual including meso-agent such as district or road network should be available within next months. These research will be carried until the end of the project to improve and enhance the first prototype, especially,

- to improve the agents' cognitive function (decision function)
- to include more classes
- to include more behaviours.

The critical other research areas in which AGENT will study from now are :

- The strategic process : how to find an appropriate sequence of operations? How to enable backtracking?
- The taking into account of macro-constraints as global density,…
- The communication and decision functions between several meso-agents.

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