Enhancing Cartographic Generalization Processing with Grid Computing Power

Theodor Foerster, Jantien Stoter & Javier Morales
International Institute for Geoinformation Science and Earth Observation (ITC), Enschede, the Netherlands
Email: {foerster;stoter;morales}@itc.nl

1. Introduction

The generation of readable maps at a specific scale by means of automated generalization is a long standing challenge (Mackaness, Ruas, & Sarjakoski, 2007; Weibel & Dutton, 1999). This so-called cartographic generalization is considered to be an optimization problem (Sester, 2005) and requires a lot of processing power depending on the specific map requirements and on the specific configuration of objects available on the map. One of the optimization approaches towards automated generalization is the agent-based approach, which has yielded promising results (Lamy et al., 1999; Regnauld & Revell, 2007). However, performance is still an unsolved issue, which becomes more urgent facing the challenge of producing readable maps for the web by the means of automated generalization.

With increasing network capabilities and processing power, distributed processing of data by means of Grid Computing has matured in the last years and is thereby promising to enhance performance of automated generalization processing. This was the starting point for developing an approach for integrating cartographic generalization processing and Grid Computing.

The paper claims that integrating the agent-based approach for automated generalization and Grid Computing is highly applicable, as the agent-based approach provides a valid means to split the processing of complete datasets into small tasks. Additionally, those tasks can run in parallel. Both aspects are crucial for integrating processes in Grid Computing (Jacob, Brown, Fukui, & Trivedi, 2005). The proposed integration is applied to a web service architecture for generating customized base maps for physical planning on the web (Foerster, Stoter, & Lemmens, 2008).

Section 2 will examine the characteristics of the agent-based generalization approach. Section 3 will demonstrate how the agent-based approach matches the requirements of Grid Computing. Additionally an architecture overview is given. Finally, the paper will discuss the approach and draw conclusions.

2. Agent-based Approach for Automated Generalization

In an agent-based generalization process, an agent is attached to a single or group of objects on the map and is able to configure and perform generalization algorithms autonomously to satisfy its state according specific requirements. Those requirements (also known as constraints) describe the conditions of the final map (e.g. the distance between two buildings should always be larger than 5 map units). The agent-based approach for automated generalization defines a hierarchy of three types of agents, to address the different types of requirements (Ruas, 2000):

- Micro agent representing a single object
- Meso agent representing a group of objects
- Macro agent representing all objects available on the map display.

The hierarchy allows the generalization process to divide the map space into small partitions (e.g. urban block), which are then attached to agents. According to the hierarchy the agents on the upper level can influence the behavior of the agents on the lower level (Figure 1).

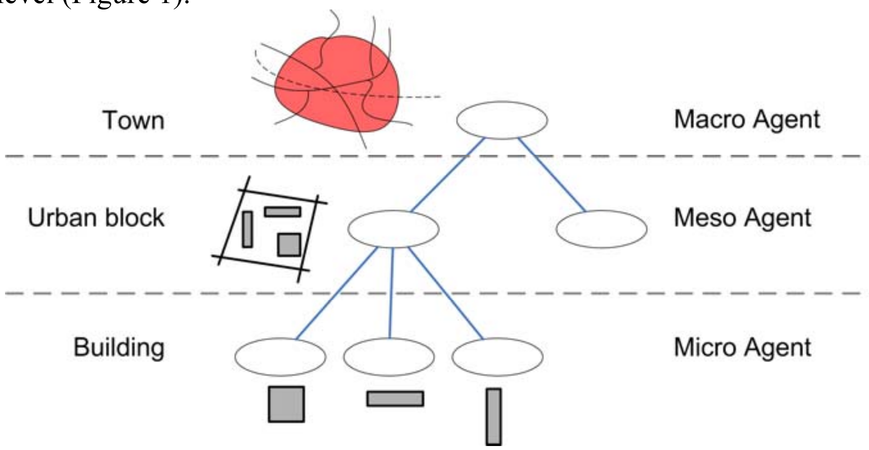

Figure 1 Hierarchy of agents (Ruas, 2000).

The agents perform the generalization according to a specific plan using a specific set of algorithms. The specific algorithms are configured and executed during the generalization process by each agent. According to the agent cycle, it evaluates the result of the applied algorithm and reprocesses the algorithm with alternative parameter configurations until its state is satisfied.

3. Architecture for a Gridified Agent-based System for Automated Generalization

Three aspects make an integration of Grid Computing and agent-based generalization highly applicable. Firstly, the agent model divides the generalization problem into small sub-problems by partitioning the map space. An agent is attached to each of the partitions. The agents configure generalization tasks, which have a small memory footprint. Secondly, the generalization tasks can run in parallel, as they are configured as atomic and do not interfere with other tasks. From a Grid Computing perspective, both aspects are considered to be crucial to use the grid infrastructure efficiently. Finally, as the generalization system runs multiple iterations to find the most applicable solutions, Grid Computing is highly beneficial for agent-based generalization processing.

The architecture for a gridified agent-based system for automated generalization is shown in Figure 2. Each agent creates a specific generalization task and submits it as a process job to the grid infrastructure. The created task consisting of process (executable code) and data (the parameters) is then handled by a grid node and the result is returned to the generalization system. According to the agent cycle the grid infrastructure is configured by many tasks at the same time and used iteratively until all the agents have reached a satisfying state. During the execution of the generalization task on the grid, the agents are not able to communicate with each other. The evaluation of the generalization result and the communication of the agents is implemented inside the generalization system.

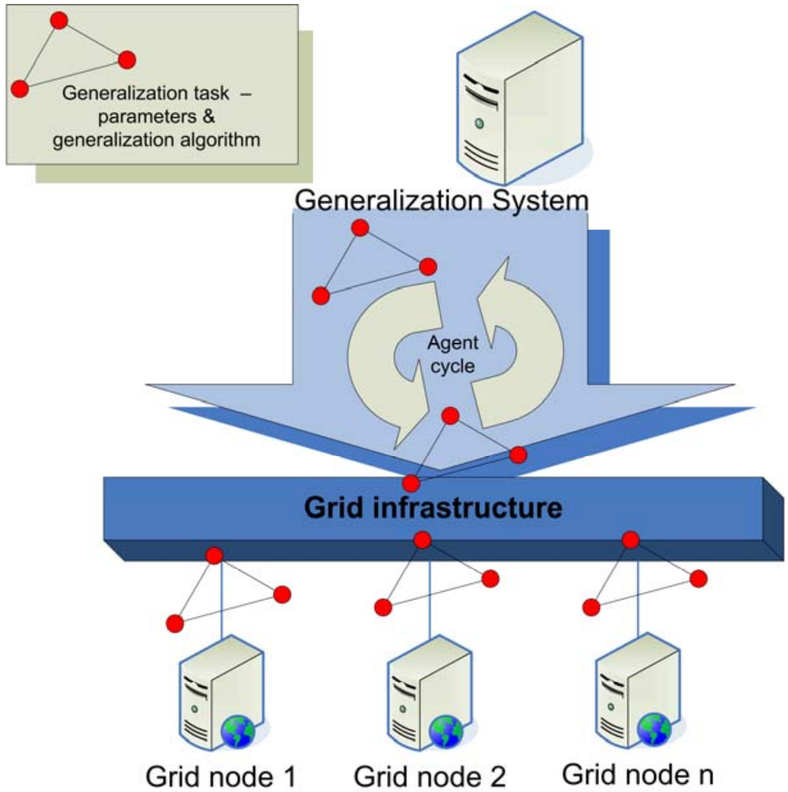

Figure 2 Architecture enabling Grid Computing access for agent-based generalization.

4. Application of the Architecture for Web-based Dissemination of Physical Planning Maps

To show its feasibility, the architecture for gridified agent-based generalization system is applied to a case study. The case study aims at disseminating of physical plans on the Web. The plans are projected on base maps, which support the communication of the planning information to a user (Poppe & Foerster, 2006). The base maps are generated from a single-scale topographic database and are customized to the specific user requirements by the means of automated generalization.

Because of different user requirements and the resulting processing effort to generate the base maps accordingly, the application of Grid Computing is highly promising. The physical planning objects provide a partition of the base map. This partition of the base map is used to set up the agent hierarchy consisting of meso agents (defined by the extent of the physical planning object) and the micro agents (defined by the base map objects).

5. Conclusion

The integration of Grid Computing and agent-based generalization is highly promising to serve on-demand and customized maps on the web.

First practical experiments regarding the generalization of the base maps have underlined the demand for such integration. Processing of hundred features takes 20-30 seconds, depending on the complexity of the object (2 CPUs @ 2.13 GHz and 2 GB of RAM). Currently only simple plans consisting of a single algorithm are applied. This shows the high demand of efficient computing for even more complex processing scenarios.

Some issues need further research regarding the implementation of our approach. In case of 1Spatial Clarity (Hardy, Hayles, & Revell, 2003), which is the reference implementation for the agent-based approach, it is a big challenge to enable agents to run in parallel. For simplicity reasons, each agent is currently applied sequentially in Clarity. Therefore the system has to be extended to realize gridified computation. Secondly, the agents have to be enabled to submit processing jobs to the grid infrastructure. Finally, there are some architectural issues which need further investigation, such as limiting the volume of data transfer to the grid at each iteration of the agent cycle. Therefore a strategy is required, which allows the agent to reconfigure specific tasks directly on the grid during the agent cycle without retransferring the data.
The insights gained by this work might also be relevant for other applications of generalization, especially when generating multi-scale databases (Stoter et al., 2008).

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