

MANAGING SPATIAL SELF-ORGANIZATION VIA COLLECTIVE BEHAVIORS

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ABSTRACT

Spatial self-organizations appear in many natural and artificial systems. Spatial systems creation and development, called morphogenesis, is the subject of many research studies since many years (2). Fractal computation approach is, for exemple, one of the methods proposed to deal with such studies. But, even if this method is able to describe unlimited local formations on multi-scale descriptions, the formation process itself is described in a global way. The goal of this paper is to introduce the distributed and decentralized computing as a general methodology to propose emergent spatial formation, able to deal with local perturbations and with non homogeneous formation rules. Both multi-criteria and multi-center systems modelling are available in the simulation processes proposed here, based on two study cases. The first study case deals with interacting population over an environment based on a regular grid. The second study case deals with intelligent swarms over an environment based on both, a stigmergic space and a geographical information system. The confrontation of these two study cases reveals the singularities of each of them and contributes to better understand the decentralized based algorithms leading to spatial emergence of self-organizations.

SPATIAL MORPHOLOGY MODELLING ON THE EDGE OF COMPLEXITY

The study of spatial morphology is a major aspect of the understanding of many phenomena for natural or artificial systems. Living systems or social systems, for example, are systems where the spatial formation has a high meaning and modifies deeply by itself the system evolution. The system evolution leads to modify itself the spatial formations by feed-back processes.

Spatial morphology models can be classified by many criteria. Some of these models are static (finding the optimal shape of some problem) or dynamic (morphogenesis, for example). When the models involve dynamical processes, these dynamics can be expressed in a global way, like we do using partial differential equations: the objective of the system description consists in describing the different phenomena involved (diffusion, transport, ...).

Spatial morphology systems can be involved inside a multi-scale processus, giving some specific properties to this multi-scale formation, like the development of important exchange area. Fractal systems are well-known to model these multi-scale systems: capacite de stockage d'air dans les poumons, fractal shape of plants, etc.

Even if these fractal geometry are able to model multi-scale description, they are generally completely deterministic and not suitable to describe geometrical evolution or to be able to integrate local disturbances. For this purpose, we need to change the model concept and go from global and deterministic models to decentralized approaches where the whole system is only known by the interaction systems of behavior population.

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GEOGRAPHICAL DATA AND ENVIRONMENT AS SUPPORT FOR EMERGENT SPATIAL SYSTEMS

Spatial morphology applied to social organizations lead to geographical systems. Nowadays, the information management for geographical systems has been greatly increase since the last decade by the development of geographical information systems (GIS). GIS allow to manage very large geographical database and allow to propose some basic computations over these database. These computations are generally suited to deal with

static data and are not adapted for the management or the analysis of dynamic systems, for their adaptive properties for exemple and more generally for their complexity . GIS need to be augmented to be able to be the support of the understanding of the geographical systems evolution. One of the innovative solution to deal with this goal is to mix GIS with multiagent systems (MAS) platform or with swarm intelligence algorithms.

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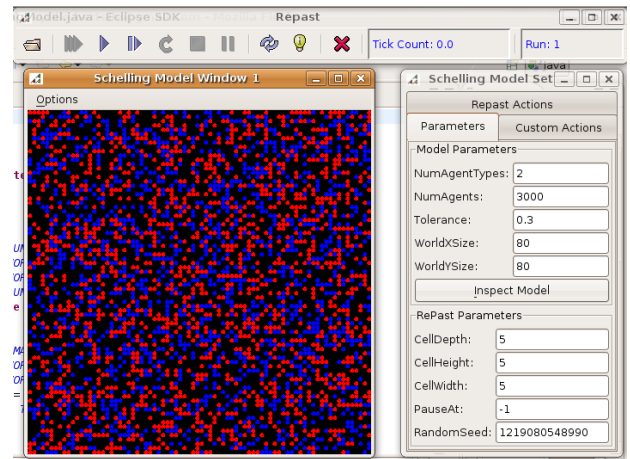
FIRST CASE STUDY: SCHELLING MODEL EXTENSION IN ORDER TO MODEL SELF-ORGANIZATION BY MEANING OF MULTI-CRITERIA SYSTEM SEPARATION

Thomas Schelling’s city segregation model illustrates how spatial organizations can emerge from local rules, concerning the spatial distribution of people which belong to different classes. In this model, people can move, depending on their own satisfaction to have neighbours of their own class. Based on this model, a city can be highly segregated even if people have only a mild preference for living among people similar to them.

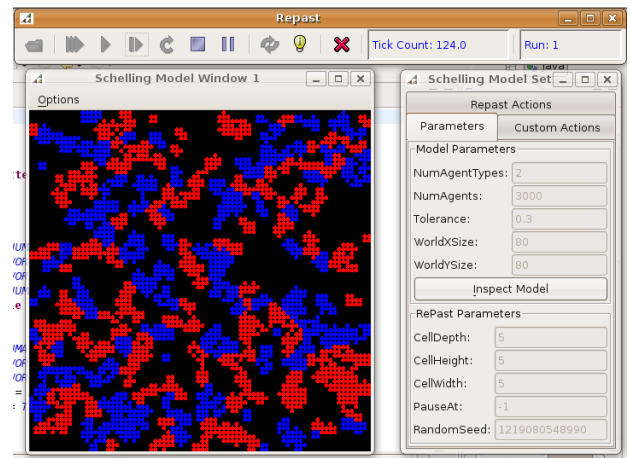
In this model, each person is an agent placed on a 2D grid (in his original presentation, a chessboard was used by Thomas Schelling). Each case can be considered like a house where the agent lives. Each agent cares about the class of his immediate neighbours who are the occupants of the abutting squares of the chessboard. Each agent has a maximum of eight possible neighbours. He computes the rate of the neighbours of its own class from its eight possible neighbours. Each agent has a tolerance rate determining whether he is happy or not at his current house location. If the rate of the neighbours of its own class is under this tolerance rate, he decides to move to live in another free place in the 2D grid.

The exact degree of segregation which emerges in the city depends strongly on the specification of the agents tolerance rate. It is noticeable that, under some rule specifications, Schelling’s city can transit from a highly integrated state to a highly segregated state in response to a small local disturbance. We can observe some bifurcation phenomena which lead to chain reaction of displacements.

In figure 1, we show an implementation of this algorithm using the multi-agent platform called Repast (11). Here, we show the “classical” and original problem, modelling the segregation phenomenon with two population classes, described by red and blue squares. Both, the initial population distribution and the final stable distribution are given.



(a) Initial situation

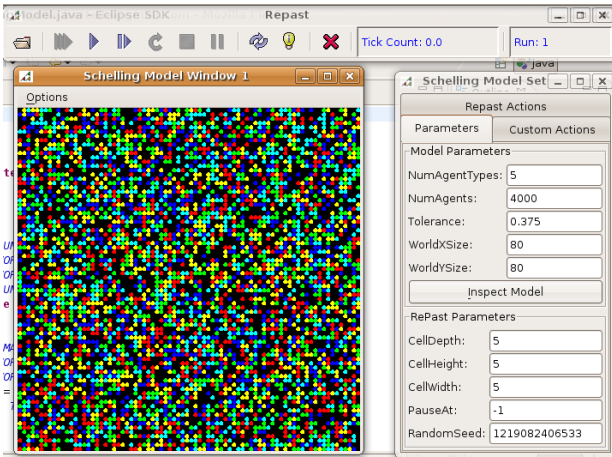


(b) Stable situation after 124 iterations

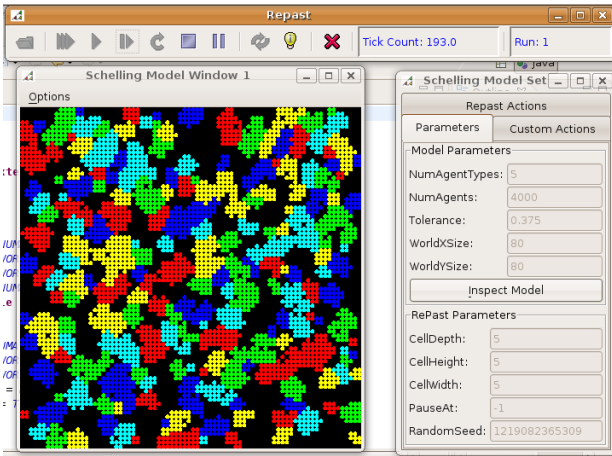
Figure 1: Standard 2 populations segregation Schelling model on Repast

In figure 2, we detail the impact of tolerance rate on the segregation result. In this figure, we extend the original problem based on 2 classes population to 5 classes population. Part (a) describes the initial distribution according to a whole population density equal to 0.625. Part (b) describes the stable population distribution for a similar tolerance rate for each agent, equal to 0.375. This value is a bifurcation point from where all small additional value lead to very different distribution. To illustrate this phenomenon, part (c) describes the population distribution for a tolerance rate of 0.3750001. the final population distribution is completely different from part (b), even if the tolerance rate is quite similar but greater.

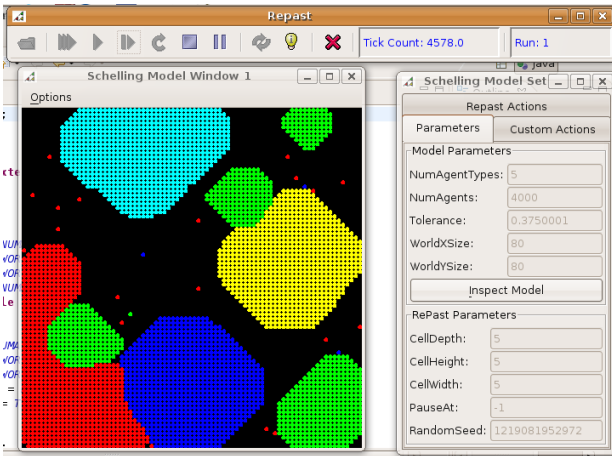
Figure 3 describe some singular formation which can appears in very few cases, when we go over the bifurcation point which lead to no clustering formation, except if some very small cluster kernels appear according to stochastic move spatial conjunction.



(a) Initial situation



(b) Final Stable situation for a tolerance rate = 0.375



(c) Final Stable situation for a tolerance rate = 0.3750001

Figure 2: 5 populations segregation Schelling model on RePast with density = 0.625 and with 2 values of tolerance rate

SECOND CASE STUDY: ANT NEST BUILDING EXTENSION IN ORDER TO MODEL SELF-ORGANIZATION BY MEANING OF MULTI-CENTER SYSTEM ATTRACTION

Urban development and dynamics are the perfect illustration of systems where spatial emergence, self-

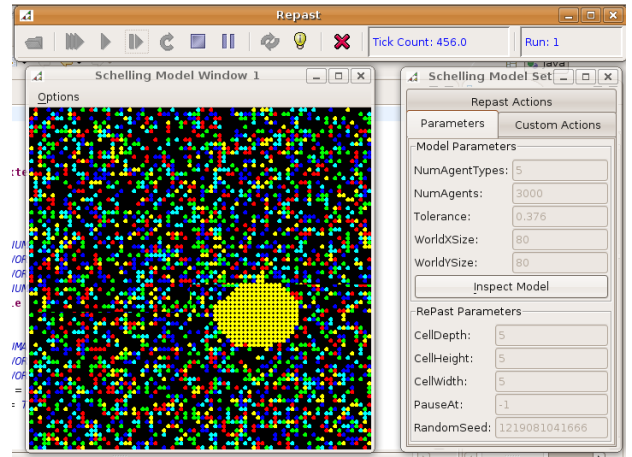


Figure 3: Singular situation for 5 populations segregation Schelling model with density = 0.47 and with tolerance rate = 0.376

organization and structural interaction between the system and its components occur. In figure 4, we concentrate on the emergence of organizational systems from geographical systems. The continuous dynamical development of the organization feed-back on the geographical system which contains the organization components and their environment.

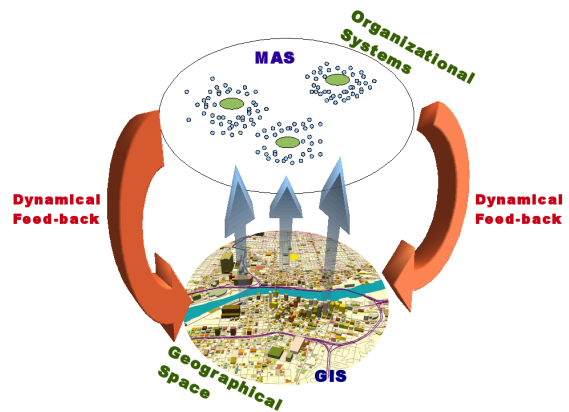


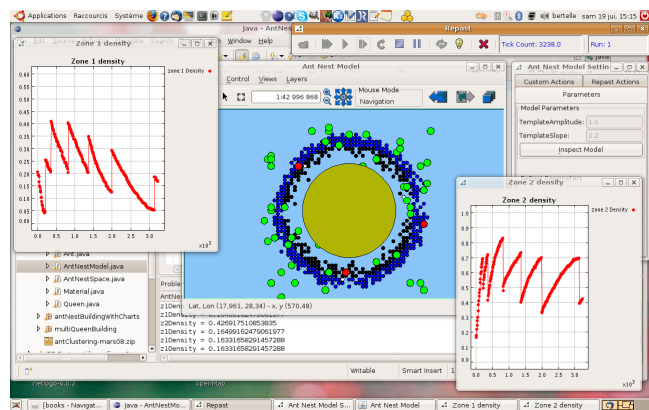
Figure 4: Complexity of geographical space with respect of emergent organizations

To model such phenomenon, we use some specific swarm intelligence technics.

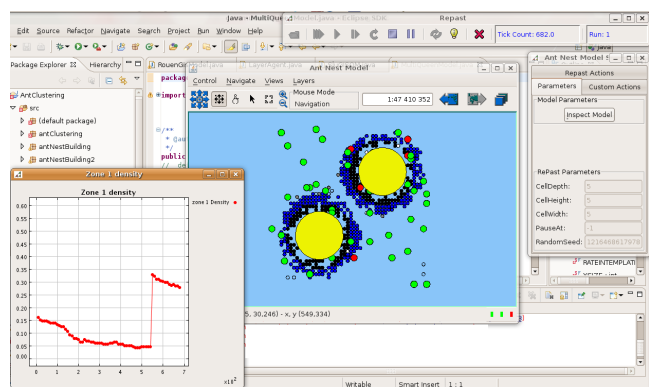
(to be completed)

In figure ??, we show an implementation of ant nest building using Repast platform. The java version of this platform includes some packages allowing to interface with geographical database and geographical infor-

mation systems (GIS). In figure ??, the graphical output windows is made under OpenMap which is a GIS developed in Java. In figure, the materials moved by the ants are the small grey circles, the ant moving without material are the green circles and the ant carrying material are the red circles.



(a) Adaptive one-center ant nest building



(b) Two-center ant nest building

Figure 5: Multi-center ant nest building using RePast over OpenMap

CONCLUSION

In this paper, we discuss about the properties of decentralized methods to model the spatial self-organization. These methods are based on the description of the whole systems by the interaction systems of interacting individual behaviors. These individual behaviors are based on rule-based systems. We present two case studies which are based on different processes: the first one use agent rule-based system over a 2D grid and the second one use intelligent swarms (ant systems) These two decentralized technics propose some specific properties to model complex systems. The first one is able to take into account multi-criteria : each population class could be understand as the characteristic of some specific criteria. And the process leads to simulate the emergent system morphology in order to define its criteria-

specific sub-population separation (as an extension of segregation problem toward multi-component morphology development) the second one is able to take into account multi-center systems and to simulate the attraction phenomenon toward these centers. Our purpose here is simply to give methodologies to model spatial self-organizations dynamics based on collective behaviors algorithms and to analyse these processes and their capacity in term of modelization. Urban dynamics, for exemple, can be better model using such methods and we will give some specific application of these methods to urban cultural dynamics in ??.

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