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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 (1). 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 homegeneous formation rules. We propose a study case on Schelling Model dealing with interacting population over an environment based on a regular grid.

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, ...).

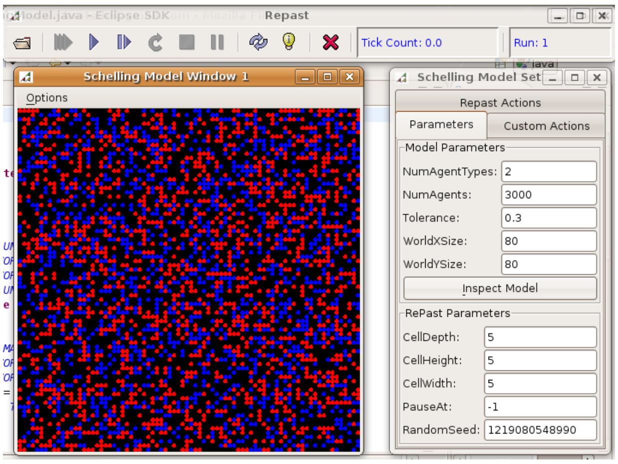
Spatial morphology systems can be involved inside a multi-scale processus, giving some specific properties to this multi-scale formation, like the development of important exchange area. Fractal systems are well-known to model these multi-scale systems like fractal shape of plants.

Even if these fractal geometries are able to model multi-scale descriptions, they are generally completly deterministic and they are not suitable to describe geometrical evolutions or to integrate local disturbations. For this purpose, we need to change the model concept and go from global deterministic models to decentralized approaches where the whole system is only known (or emerge) by the interaction system of behavior population.

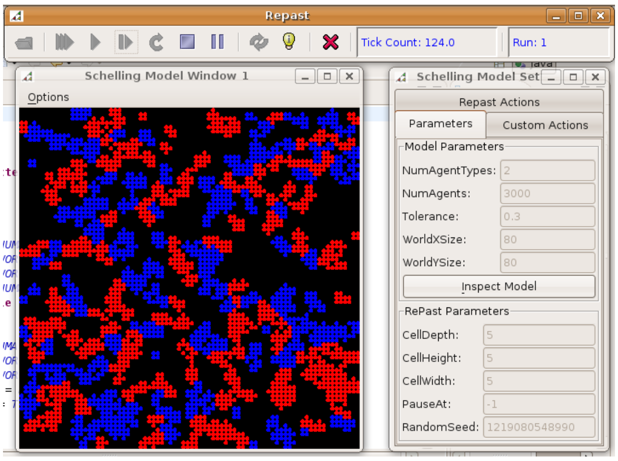
SCHELLING MODEL EXTENSION IN ORDER TO MODEL SELF-ORGANIZATION BY MEANING OF MULTI-CRITERIA SYSTEM SEPARATION

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 tolerence 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 tolerence rate, he decides to move to live in another free place in the 2D grid.



(a) Initial situation

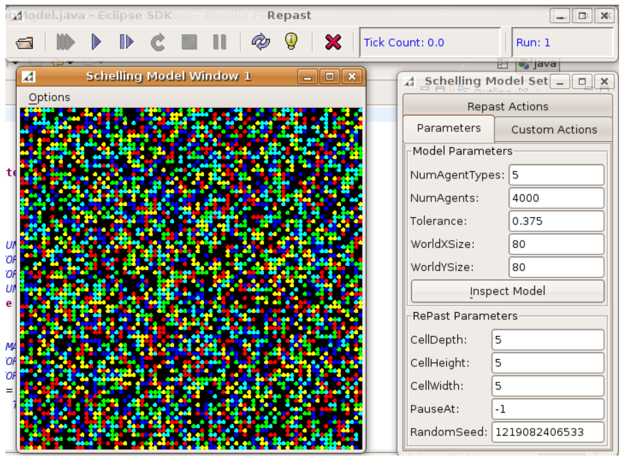


(b) Stable situation after 124 iterations

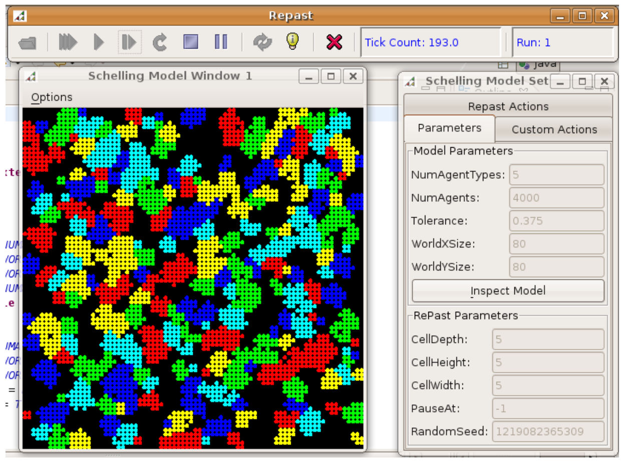
Figure 1: Standard 2 populations seggregation Schelling model on RePast

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.

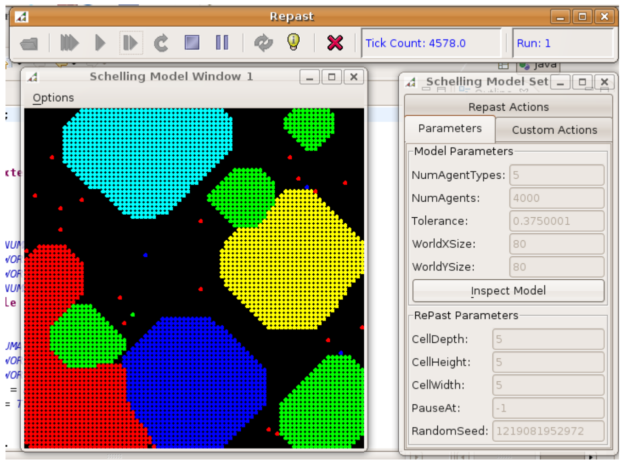
In figure 1, we show an implementation of this algorithm using the multi-agent platform called Repast (7). Here, we show the "classical" and original problem, modelling the segregation phenomenon with two population classes, described by red and blue squares. Both,



(a) Initial situation



(b) Final Stable situation for a tolerence rate = 0.375, corresponding to 3 neighbours over 8



(c) Final Stable situation for a tolerence rate greater than 0.375 and corresponding to 4 neighbours.

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

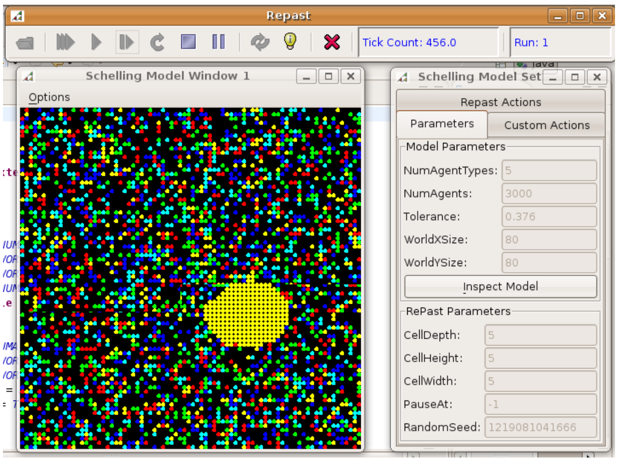


Figure 3: Singular situation for 5 populations seggregation Schelling model with density = 0.47 and with tolerance rate = 0.376

the initial population distribution and the final stable distribution are given.

In figure 2, we detail the impact of tolerence rate on the segregation result. In this figure, we extend the original problem based on 2 population classes 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, corresponding to 3 neighbours on 8. This value is a *discrete* bifurcation point from where all small additional value leads to a very different distribution. To illustrate this phenomenon, part (c) describes the population distribution for a tolerance rate greater than 0.375, corresponding to 4 neighbours. The final population distribution is completly different than the one in part (b).
Figure 3 describe some singular formation which can appears in very few cases, when we go over the bifurcation point which leads to no global clustering formation, except if some very small cluster kernels appear according to stochatic move spatial conjonction.

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 system by the interaction systems of individual behaviors. We present some experiments on Schelling's model where auto-organization emerge from local rules. This model is able to take into account multi-criteria : each population class could be understand as the characteristic of some specific criteria. And the processus 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).

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