Adaptive Automata Community Detection and Clustering - A generic methodology -

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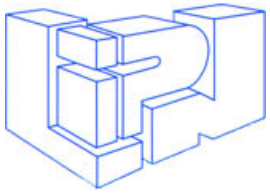
ICCIIS'07 - WCE

July 2-4, 2007 London, UK



Outline

Context and Objectives

- Complexity theory cover wide area of Systems in Science, making relevant links between social, biological and physical systems;
- In these complex systems, spatial structures emerge from interacting entities crossed by energetic fluxes;
- These emergent spatial structure are self-organizations, controled by some global objectives;
- The communities computed in the following respect these characteristics.

Complexity Concept Approach

Complexity Analysis is based on conceptual functions:

- Complexity is based on multi-description
  - Multi-scale, Multi-actor and Multi-disciplinary
  - Micro/Macro interaction in multi-scale description
- Emergent self-organizations and associated morphologies
  - Dynamic of the organizations: their evolution and their adaptation
  - Hierarchical structure of organization
  - Organization feed-back on the entities (country laws feed-back on the cities management)

Outline

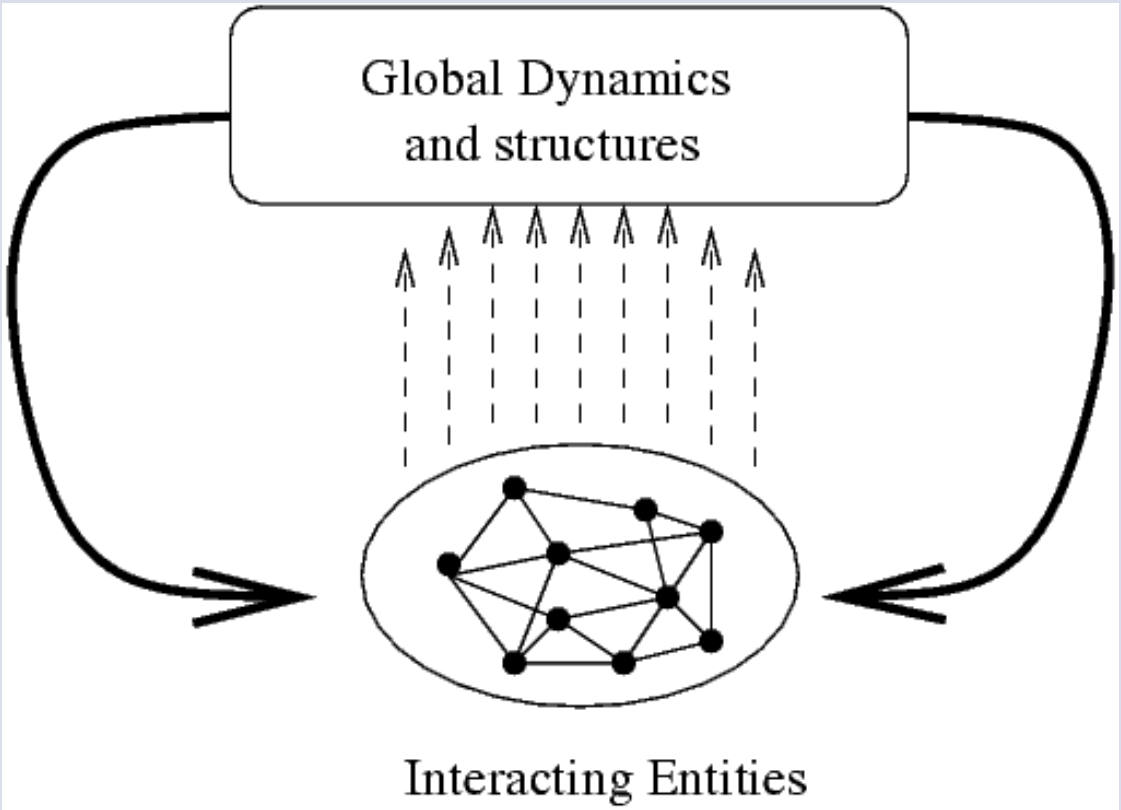
Self-Organization Modeling

Emergent Computing Classification

- Cellular Automata (CA) can model urban land-use or regional dynamics.
  - From Schelling's model, we can study by CA simulation, the segregation-like phenomena
- Agent-based modelling extends the basic diffusion rules of CA to more sophisticated behavioral processes.
  We developped in the following our specific agent behavior modeling using automata with multiplicities.

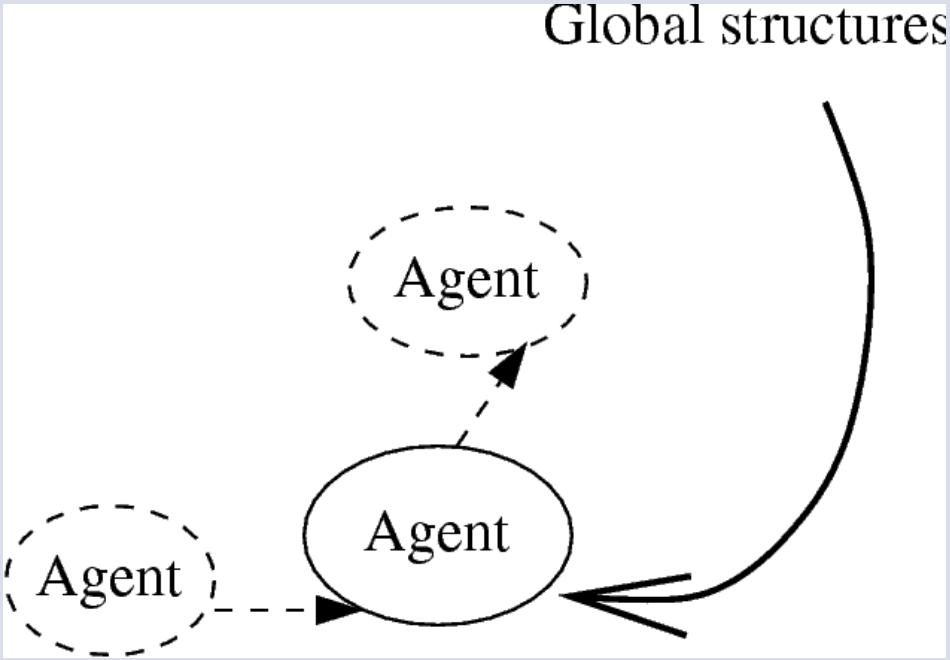
Agent-Based Modeling

Multi-agent for complex systems



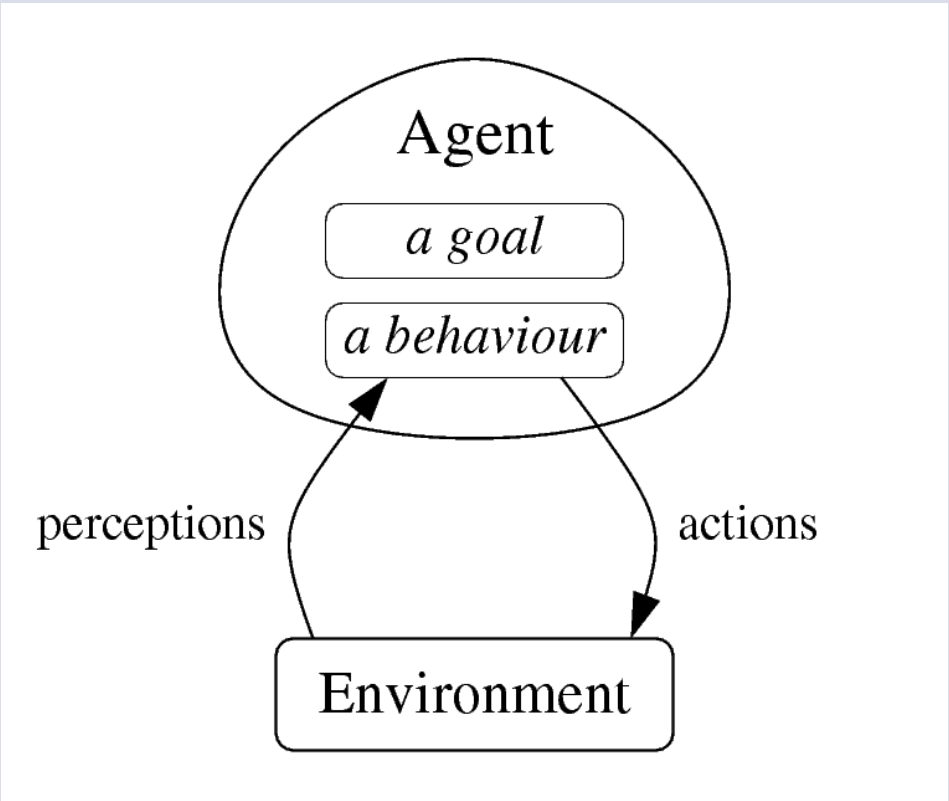
Agent-Based Modeling

Interactives Agents System



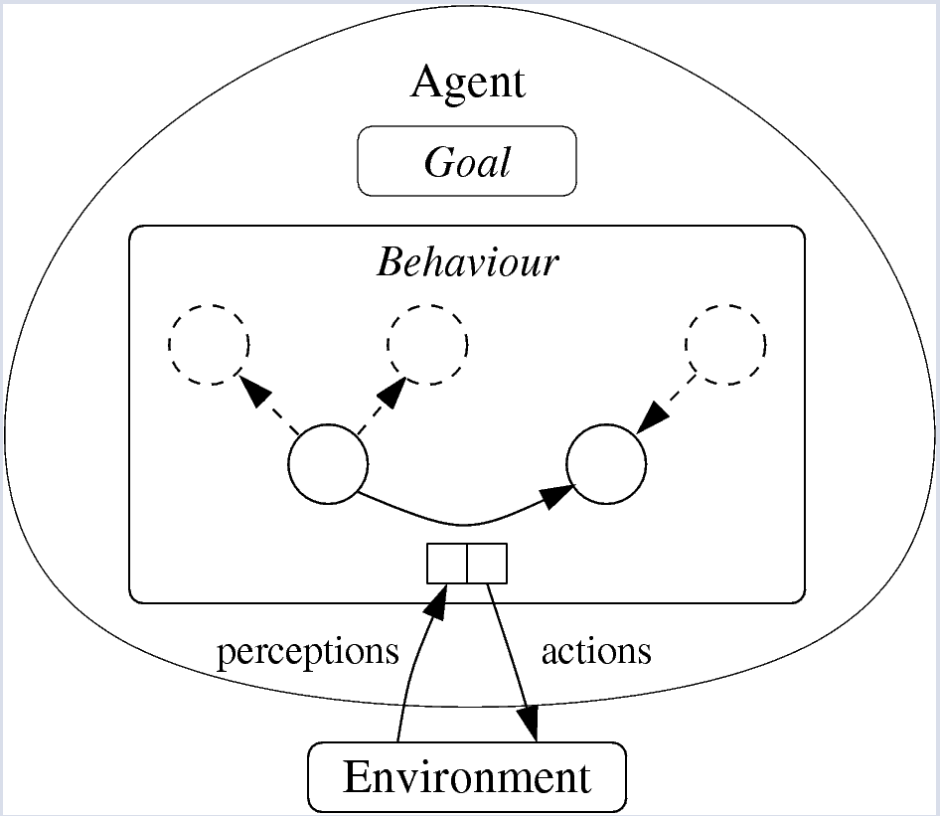
Agent-Based Modeling

Agents modeling



Agent-Based Modeling

Automata-based Agent Behavior



Automata-based Agent Behavior Modeling

Automata with multiplicities

Agent behavior is modelled by automata with multiplicities which is defined by

- A set of perception represented by an alphabet
- A set of actions represented by a **semi-ring** K
- A set of states with a subset of initial states and a subset of final states
- A set of transitions between states which is generate by a perception in input and which generate an action in output

Automata-based Agent Behavior Modeling

Automata with multiplicities

Because the set of actions K is a **semi-ring**,

- we can represented the automata using a linear representation (vectors and matrices),
- we can defined many kinds of operators on these automata and so improve automatic processes on agent management

Example

- Strategy modeling using *probabilistic* automata for game theory
- Automata based model for player behavior with adversory
  - 2 behavioral states: Cooperate (s1: C) or Defect (s2:D)
  - Probabilistic transition from one state to another according to what make the adversory at the previous step

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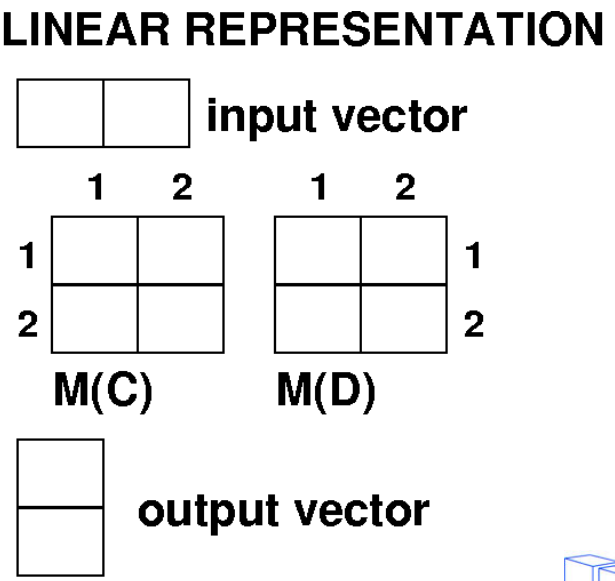

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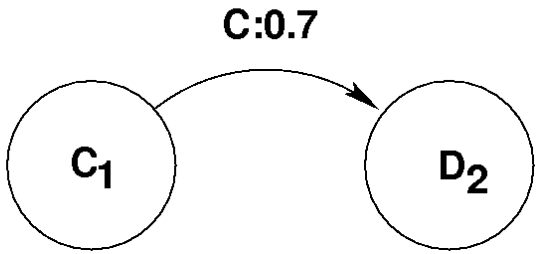

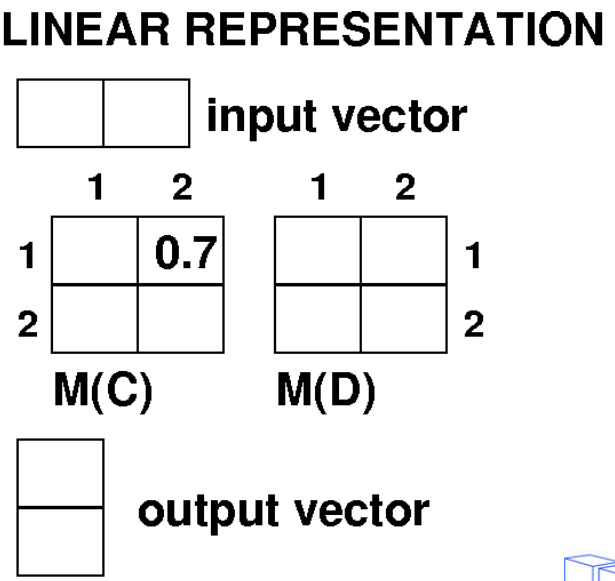

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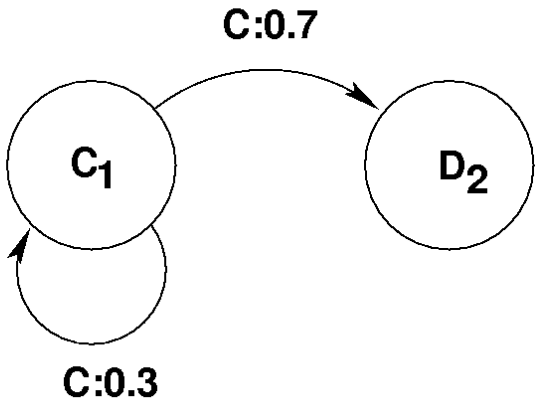

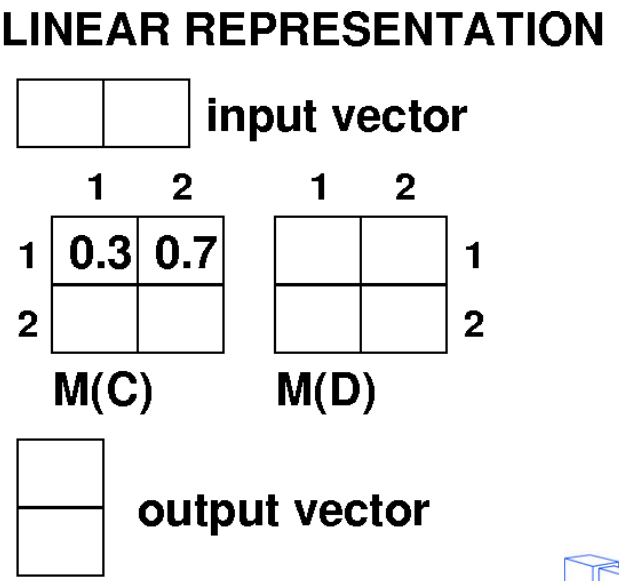

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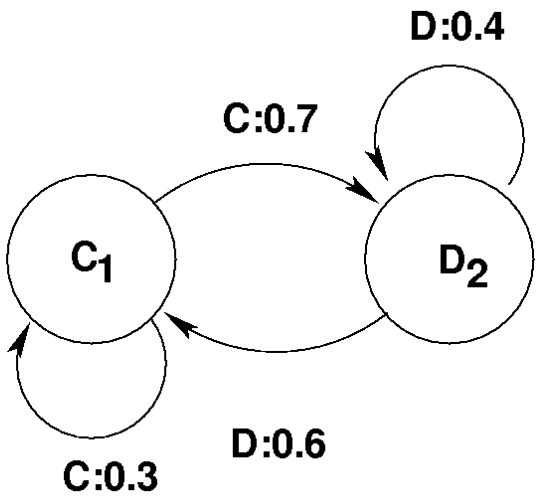

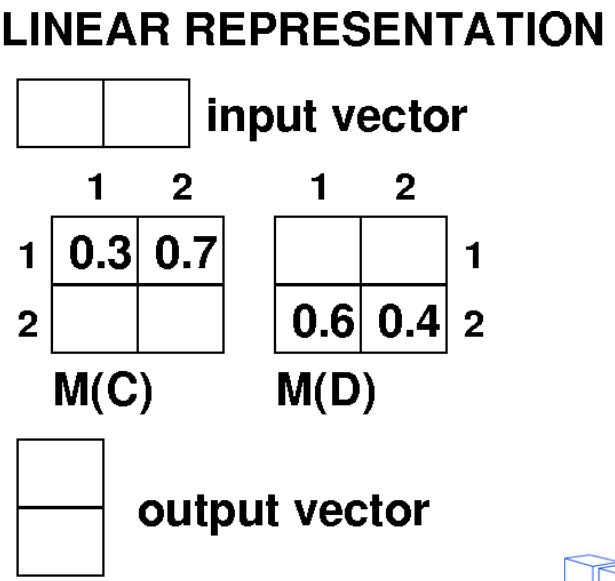

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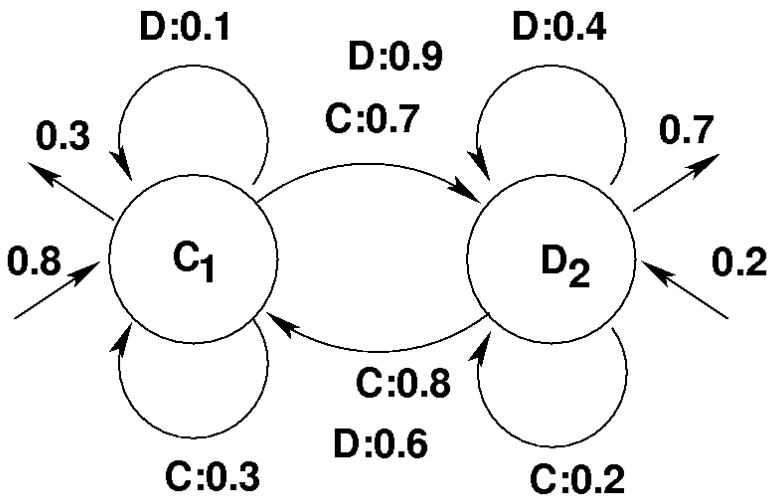

LINEAR REPRESENTATION

0.8	0.2

input vector

M(C)

	1	2
1	0.3	0.7
2	0.8	0.2

M(D)

	1	2	
1	0.1	0.9	1
2	0.6	0.4	2

0.3
0.7

output vector

Outline

Spatial and Behavioral Modeling Based on Community Detection

Spatial agent and associated distances

- A spatial agent is defined by
  - Spatial coordinates
  - A behavior modeled by an automaton with multiplicities
- A **spatial distance** between 2 agents, can be computed according to their spatial coordinates
- A **behavioral distance** between 2 agents can be compute by the distance between the vectors which stores all the coefficients of the linear representation of the agent behavior automata.

Spatial and Behavioral Modeling Based on Community Detection

Community Definition

- A **community** is a system or an organization which is characterized by a ***spatial*** property, a ***behavior*** property and the interaction between the both.

Spatial and Behavioral Modeling Based on Community Detection

Genetic operators on automata

- Using the matrix representation of the automata with multiplicities, we can defined the classical genetic operators: duplication, crossing-over and mutation, using a chromosome composed of each lines of the matrices of the linear representation.

Example ... following

Genetic on strategy modeling for player behavior

- Genetic operators deal with **population** of **individuals** (here player behavior modeled by automata).
- **Individual** is described by a **chromosome** which is a sequence of **alleles** (elementary information).
- Here, the chromosomes are coding the transition matrices of the automata linear representation.
- Here, an allele is a matrix line ...

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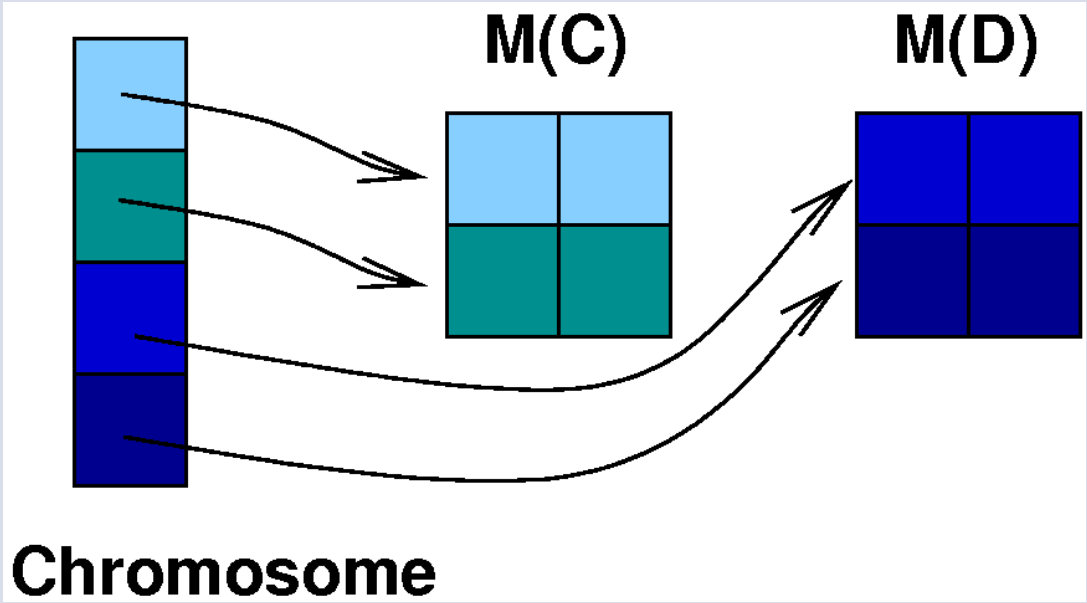
Example ... following

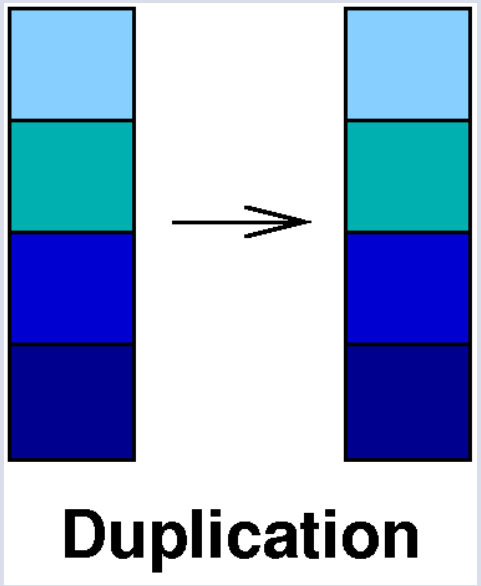
Genetic on strategy modeling for player behavior

- ... and the chromosome is the set of the matrix lines of all the transition matrices



Example ... following

Genetic operators



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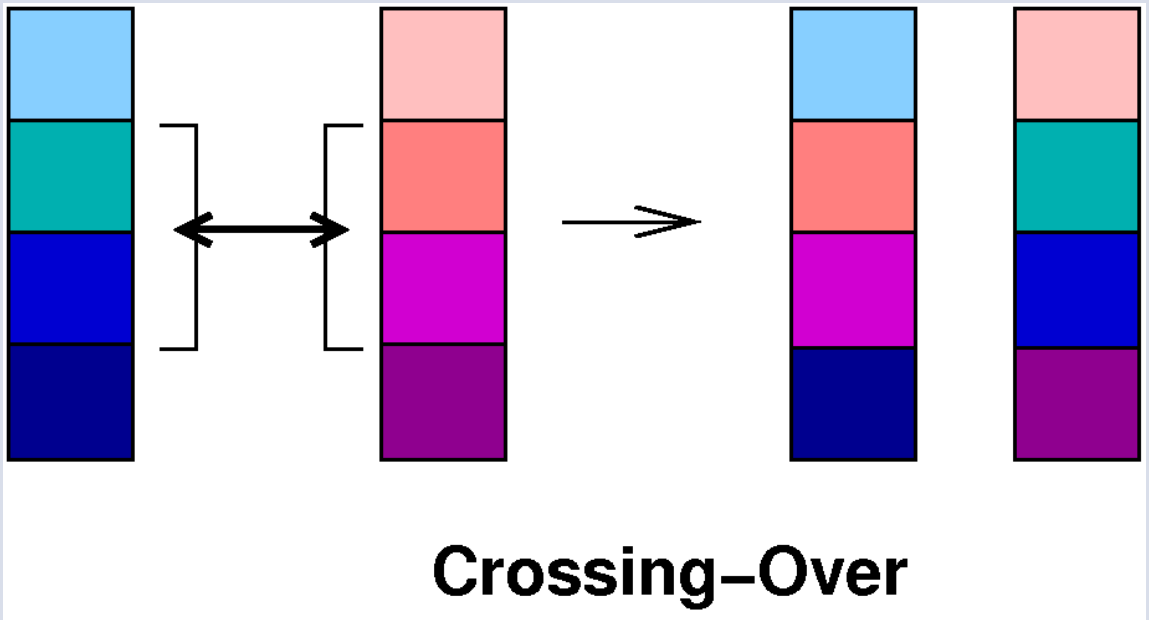

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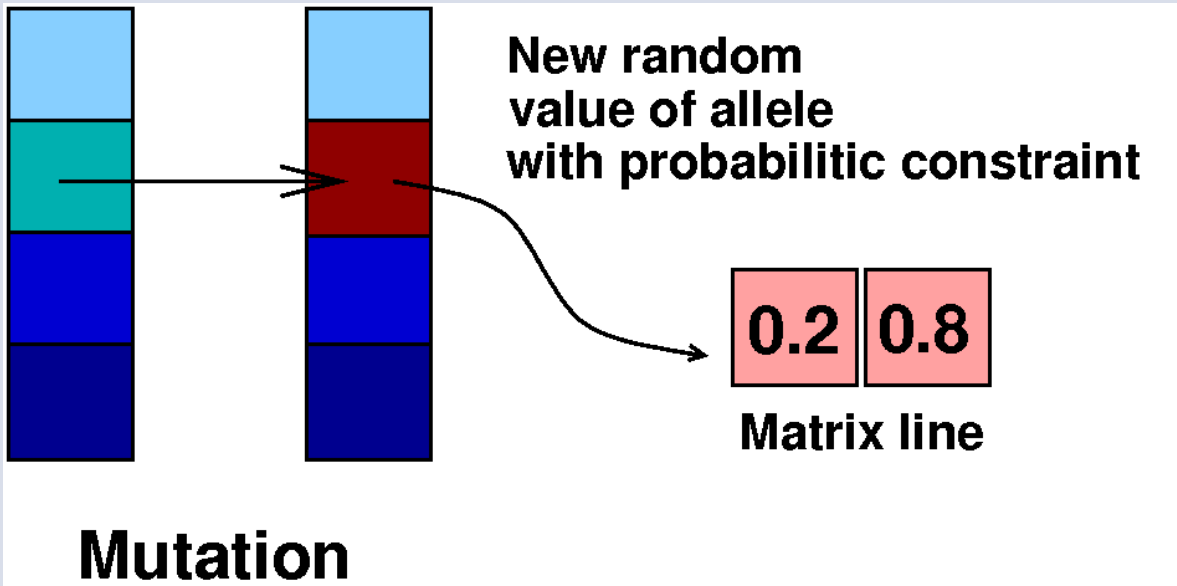


Spatial and Behavioral Modeling Based on Community Detection

Community Detection associated to fitness function

- We can defined the fitness of each agent as following:
  - We compute his neighbourhood, using the ***spatial distance***
  - We sum the ***behavioral distance*** of the agent itself with all the others agents included in the neighbourhood
  - We define the fitness as the inverse of the average of the previous sum.
- Self-organization communities emerge from the use of this fitness inside a genetic algorithm.

Spatial and Behavioral Modeling Based on Community Detection

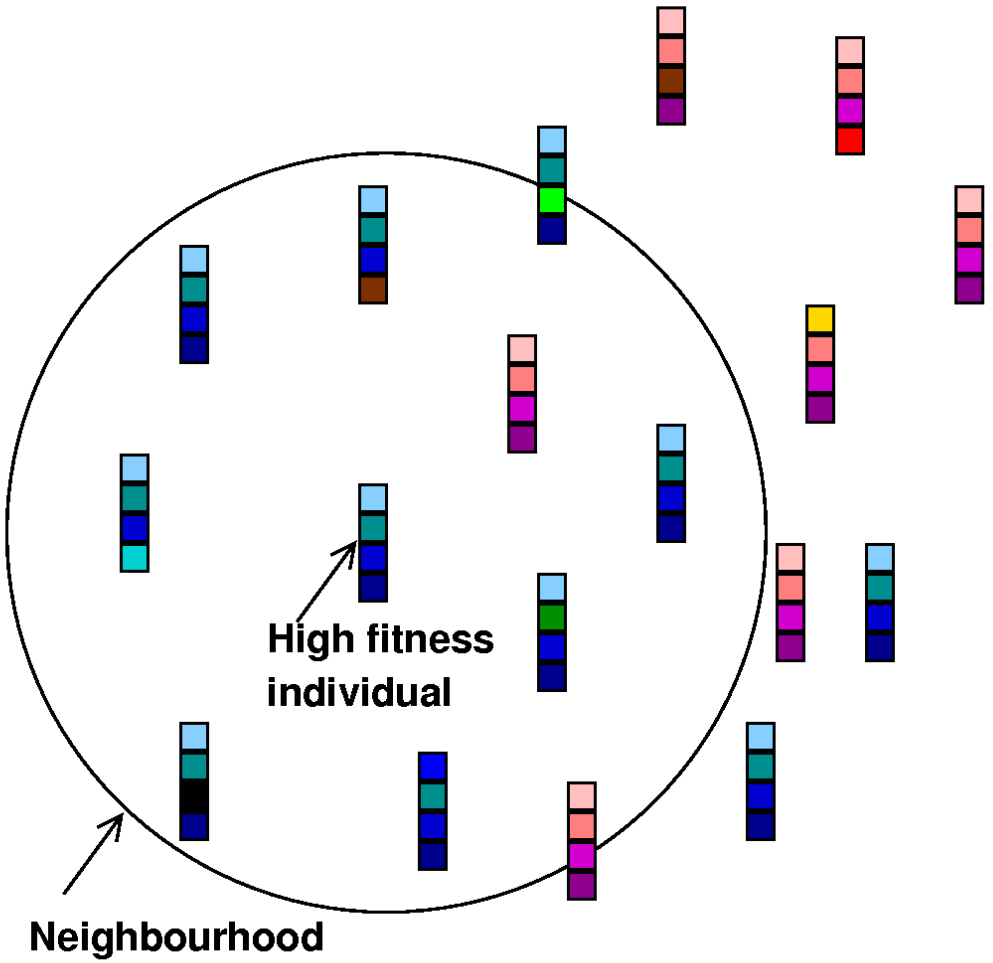
Community Detection associated to fitness function

Let $\mathcal{V}_x$ a neighbourhood of the agent x, relatively to its spatial location. We define $f(x)$ the agent fitness of the agent x as :

$$f(x) = \begin{cases} \dfrac{card(\mathcal{V}_x)}{\sum\limits_{y_i \in \mathcal{V}_x} d(x, y_i)^2} & \text{if } \sum\limits_{y_i \in \mathcal{V}_x} d(x, y_i)^2 \neq 0 \\ \infty & \text{otherwise} \end{cases}$$

where $d(x, y)$ is the behavioral semi-distance between the two agents x and y.

Example ... following



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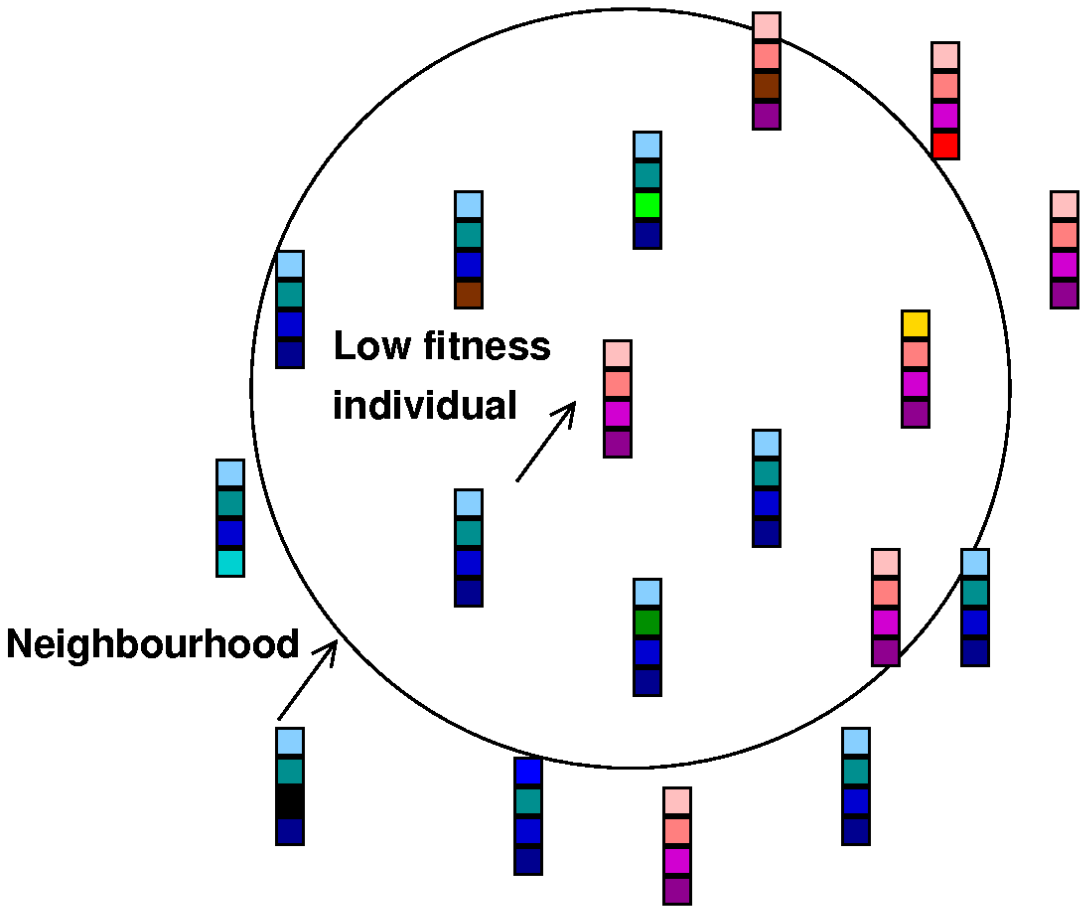


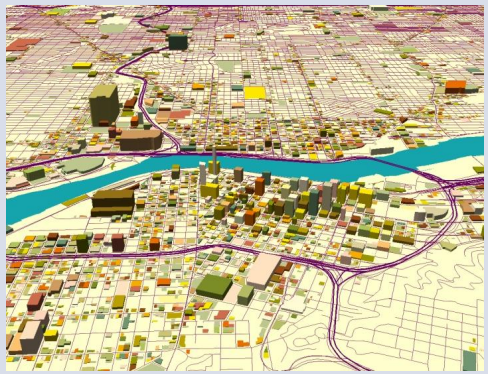
Outline

Application :GIS and Agent-Based Modeling Mixing

Geographical Information Systems - GIS

Nowadays, the geographical information is a very wide knowledge database

- GIS allow to store, manage and compute all this information
- Wide-world communication improve the interaction networks dealing with Geo-Politic



Application :GIS and Agent-Based Modeling Mixing

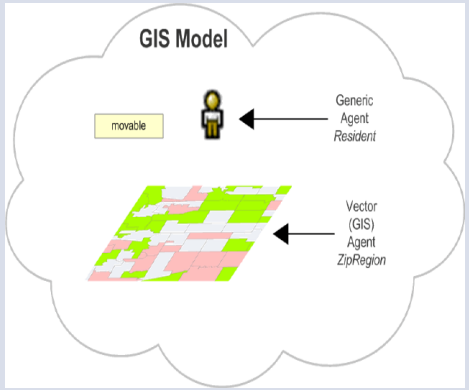
Geographical Information Systems - GIS

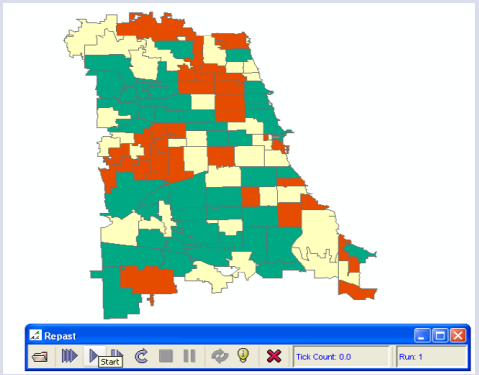
→ The future improvement of GIS with automatic self-organization processes (like the communities detection proposed) can be one of the major aspect of the increasing of the world complexity to be controled as a whole, with the tools from the complexity concepts

Application :GIS and Agent-Based Modeling Mixing

Agent-based mixing

- Our goal is to include the community detection as a agent-based self-organization processus inside GIS
- We use Repast and its extension proposed by ESRI: Agent Analyst





Outline

Conclusion and Perspectives

The future of the methodology and its applications

- The methodology proposed here, is based on community clustering (spatial and behavioral control) emerging from complex evolutive agents systems described by automata
- Concrete applications can be developped using GIS mixed with adaptive/genetic agent modeling
- Practical applications can be various and are under development now, specificaly on urban dynamics (economical, environmental, social or cultural development)