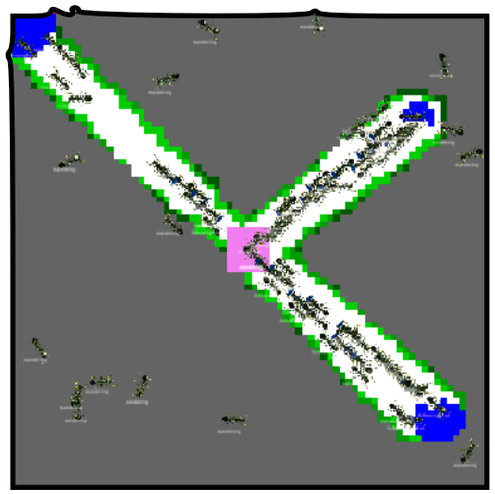
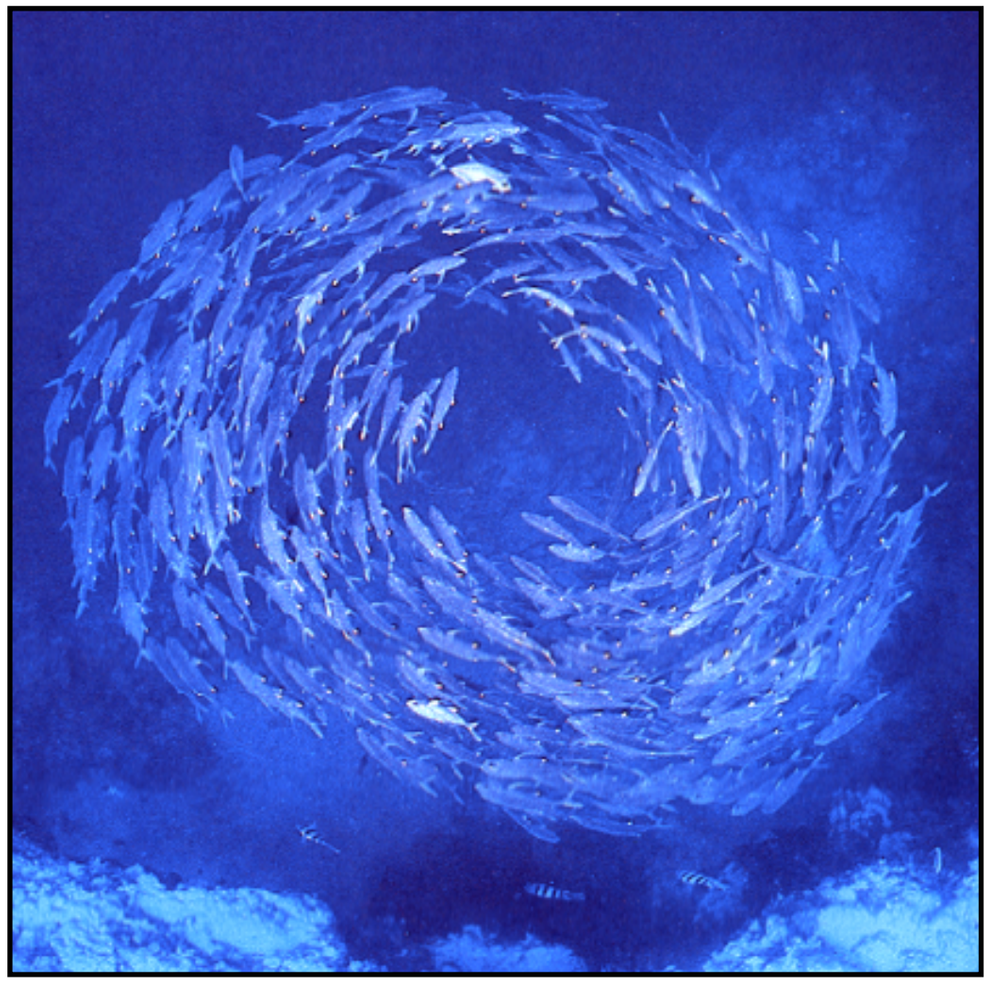
Agent, Multi-Agent Systems and Agent-based Modelling and Simulation





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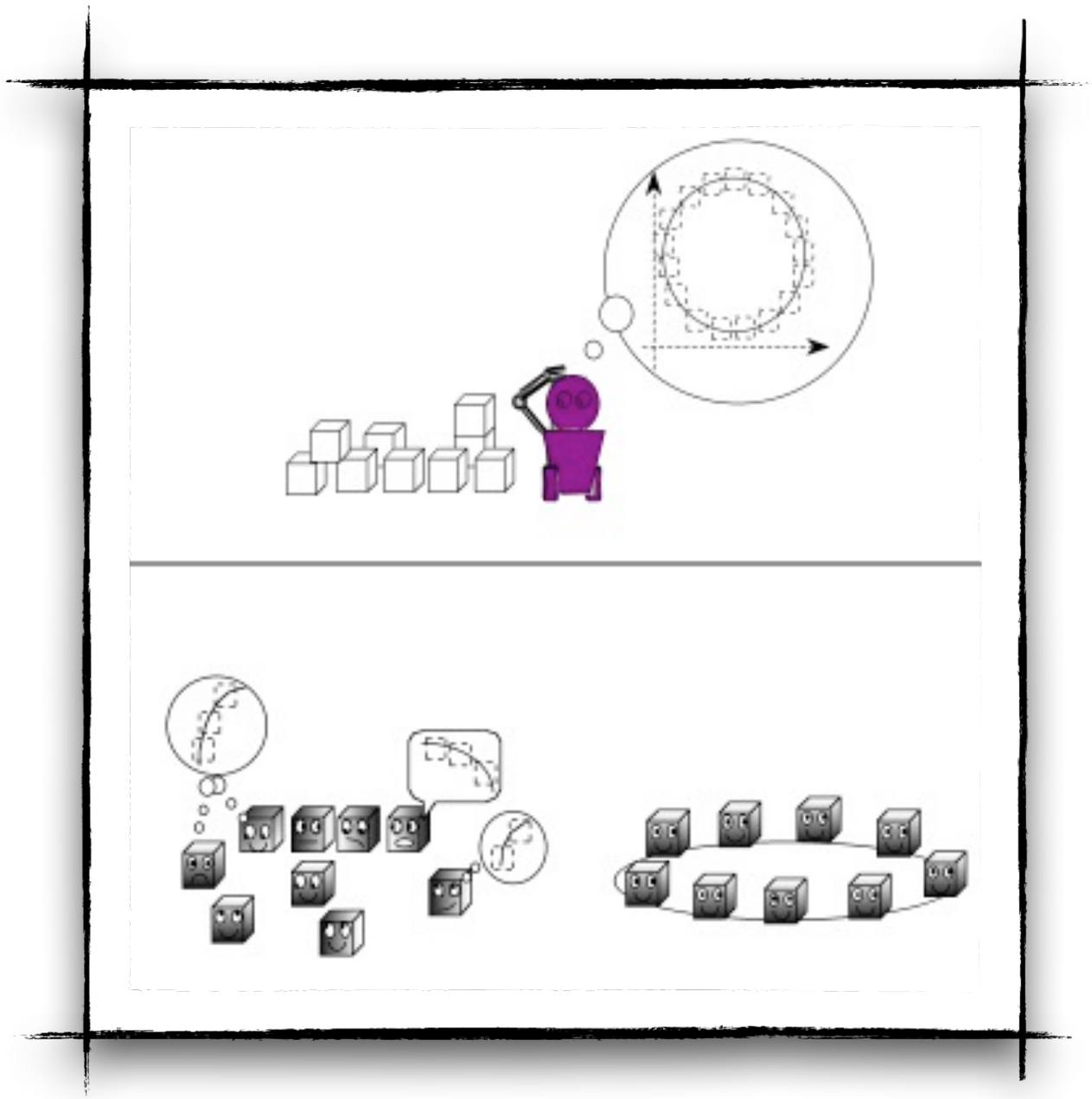
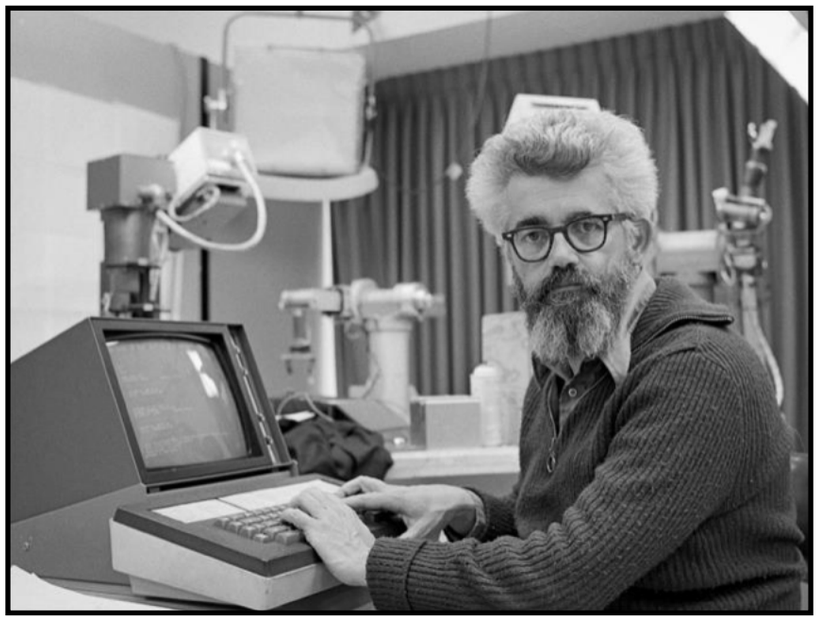
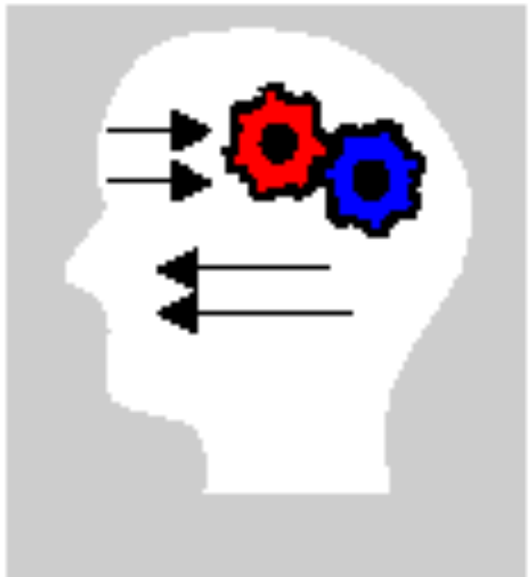
Introduction



In 1956, John MacCarthy organized the first workshop about Artificial Intelligence.

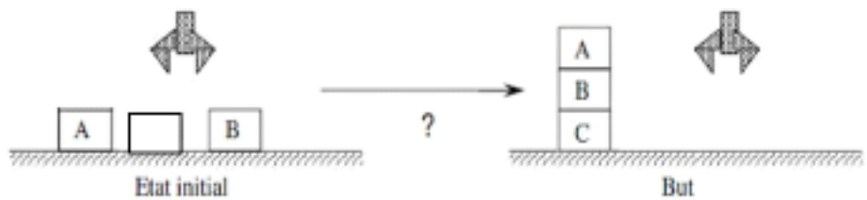
- In AI, the basic model is the **individual intelligence**.
  E.g.:
  - Planner (STRIPS 1971)
  - Expert systems.





The expert

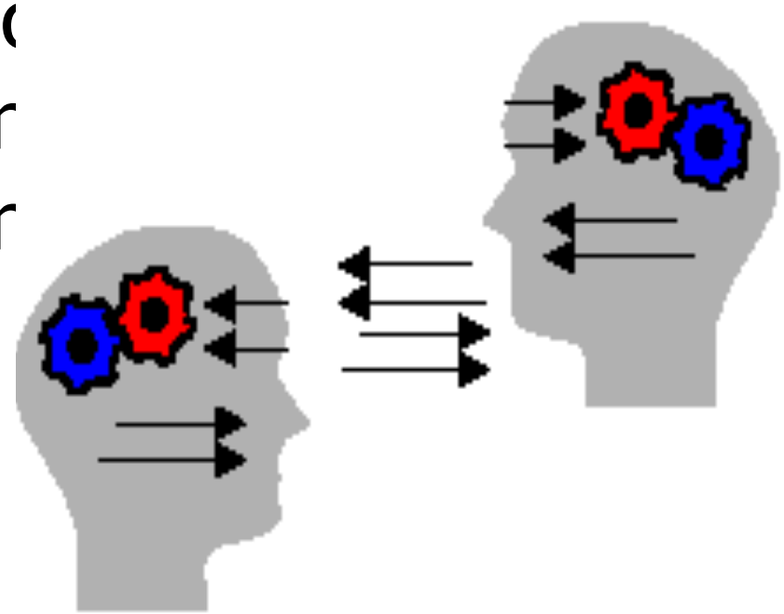
STRIPS planner




```
(:action stack
   :parameters (?x – block ?y - block)
    :precondition (and (holding ?x) (clear ?y))
    :effects (and (not (holding ?x)) (not (clear ?y))
                  (on ?x ?y) (clear ?x) (handempty))
```

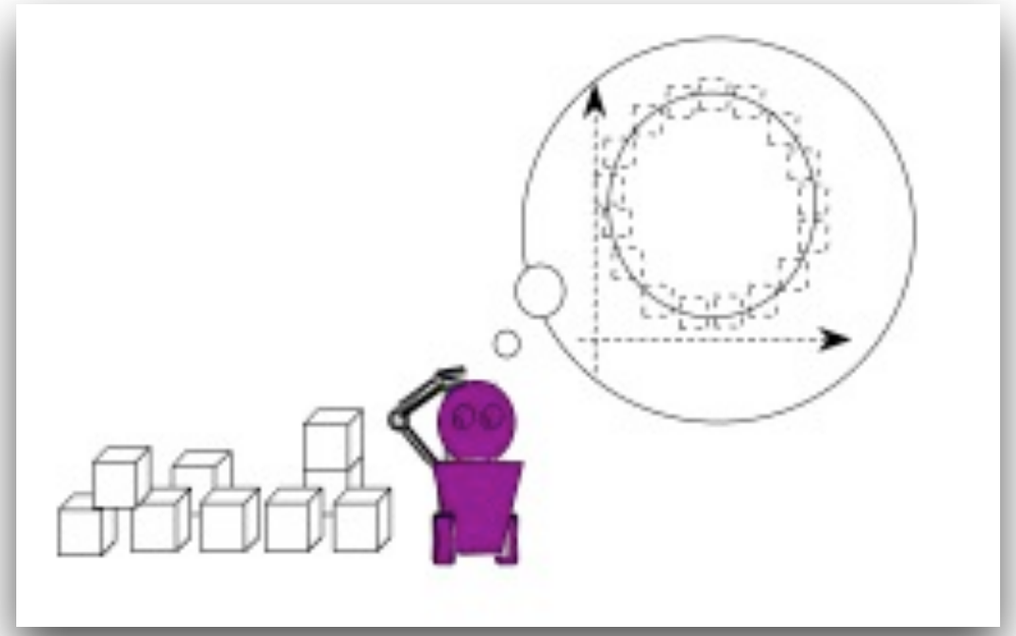
In 80's, Distributed AI (1980) (among others) appear in opposition to AI.

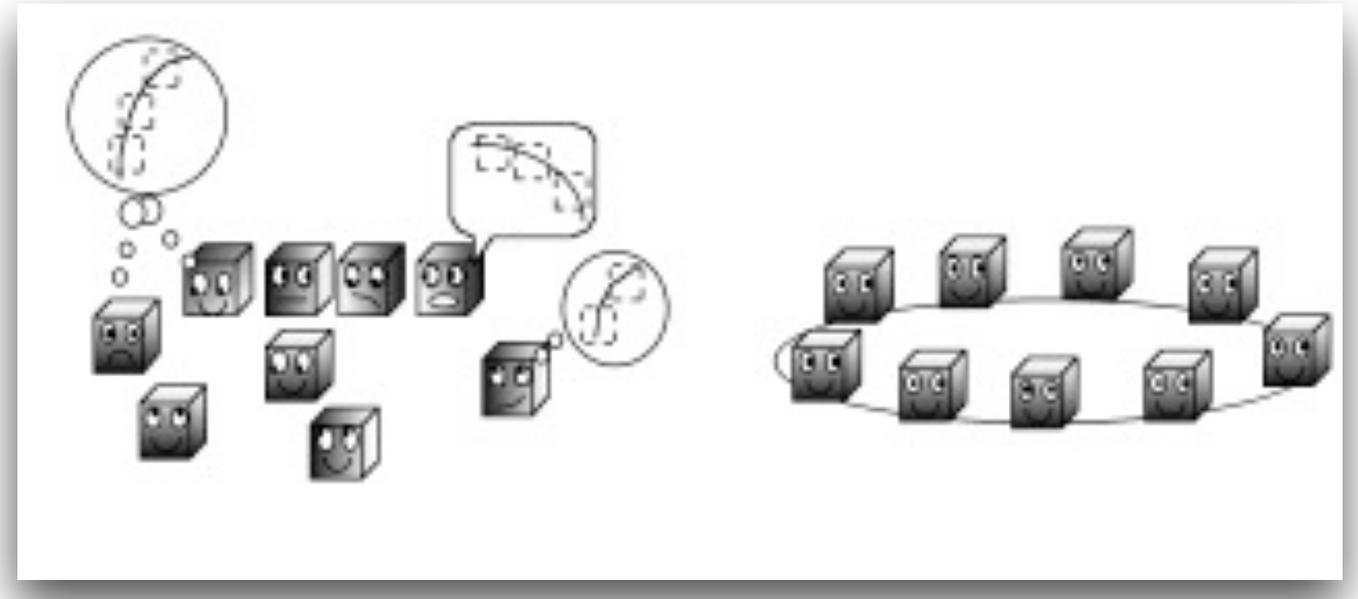
- Instead of considering only cognitive faculties of an individual, **DAI** postulates that intelligence "**emerges**" from the interacti
between agents ar
between agents ar
environment.



A community

AI vs DAI on a problem:
How to draw a circle with boxes ?

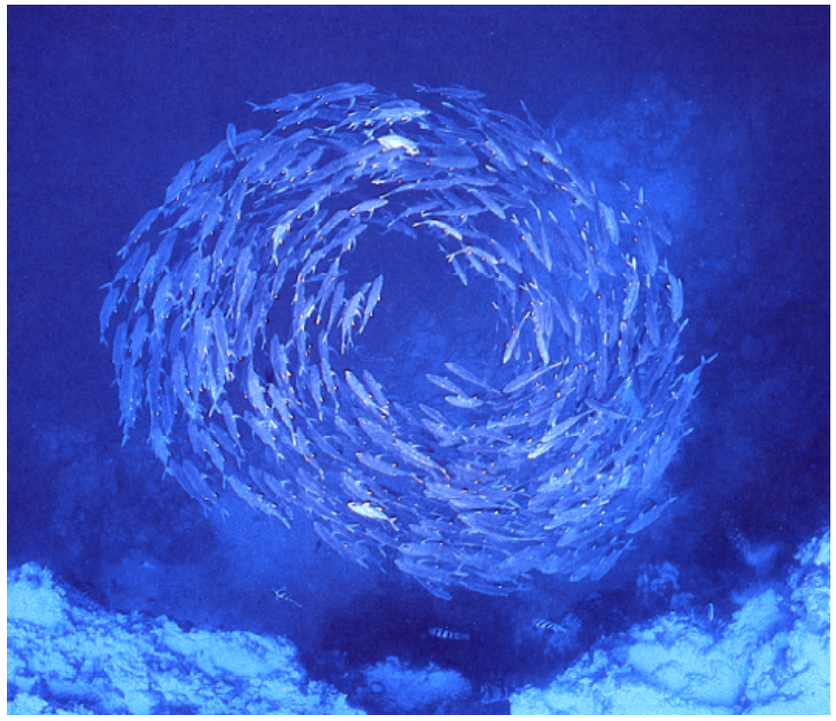


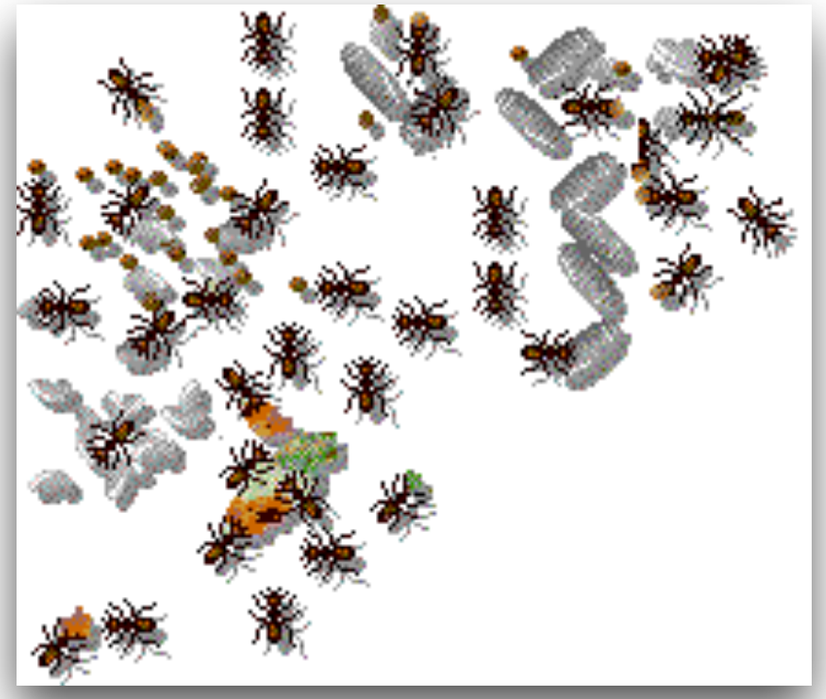


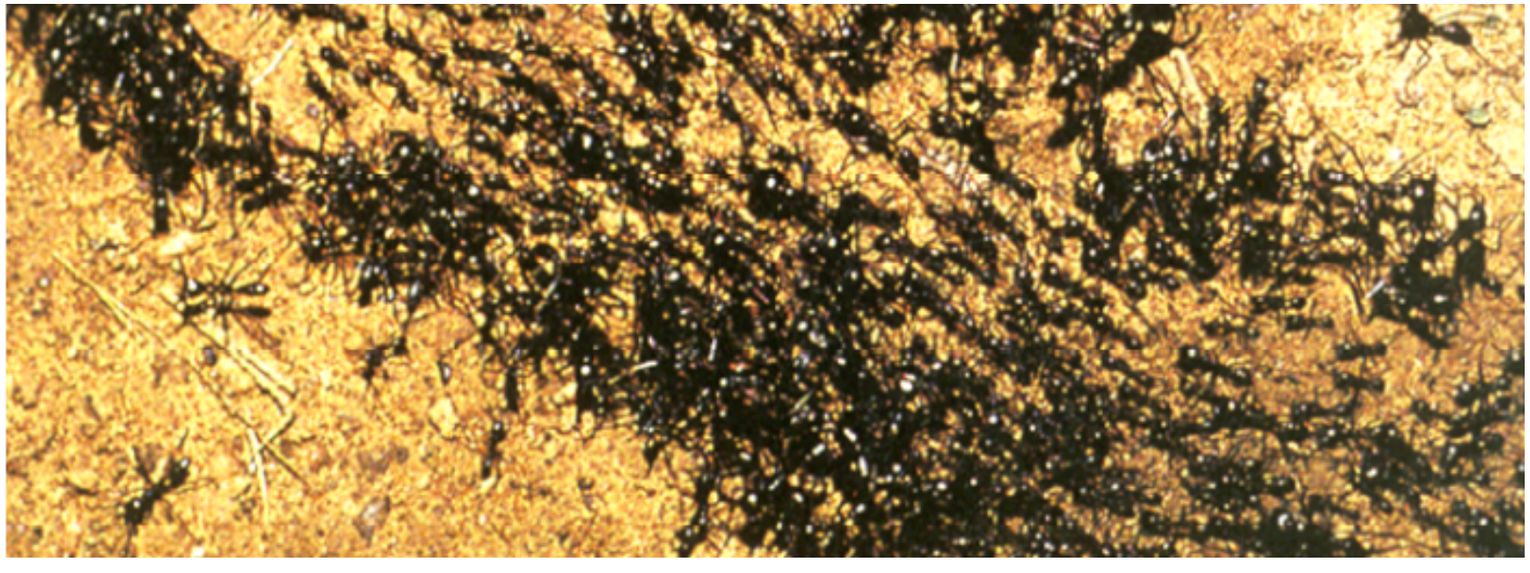
Example of M.Huhns (96)

Multi-Agent Systems are interested in complex systems where artificial and/or natural entities interact to produce collective behaviors.

- MAS is interested in complex systems where artificial and/or natural entities interact to produce collective behaviours.

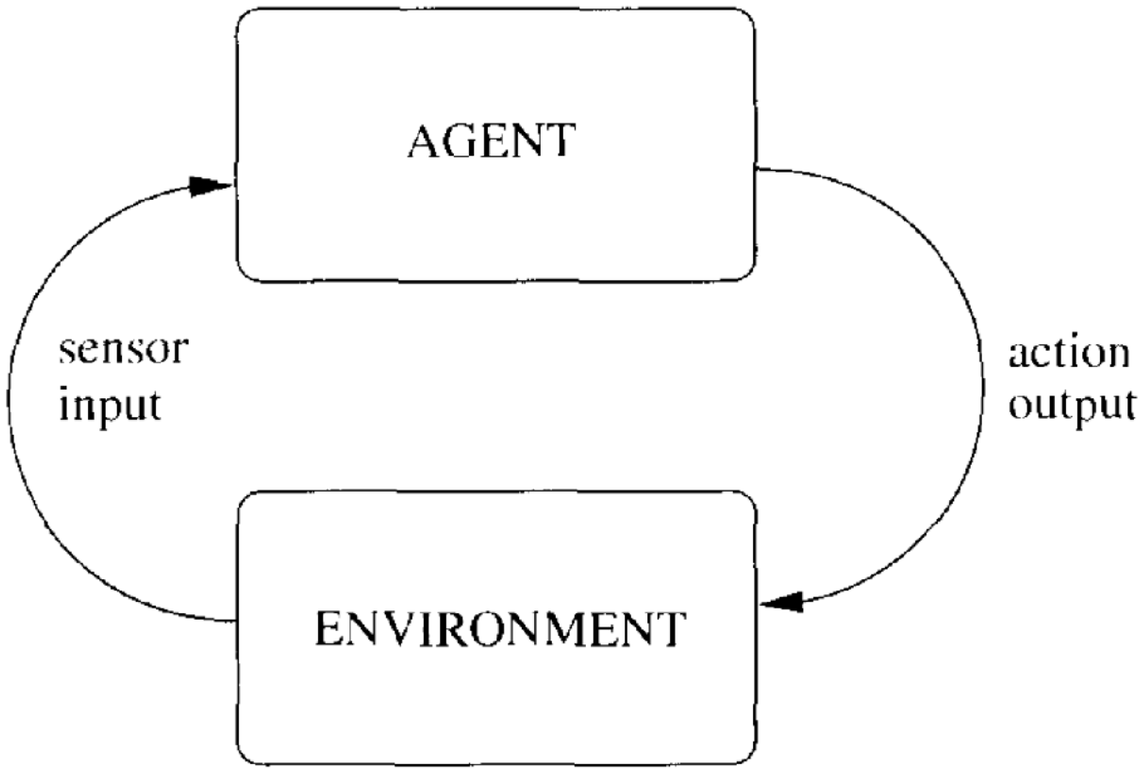






What is an agent?

- An agent is a computer system that is situated in some **environment**, and that is capable of **<u>autonomous</u> action** in this environment in order to meet its **design objectives**. (Wooldridge, 2008)



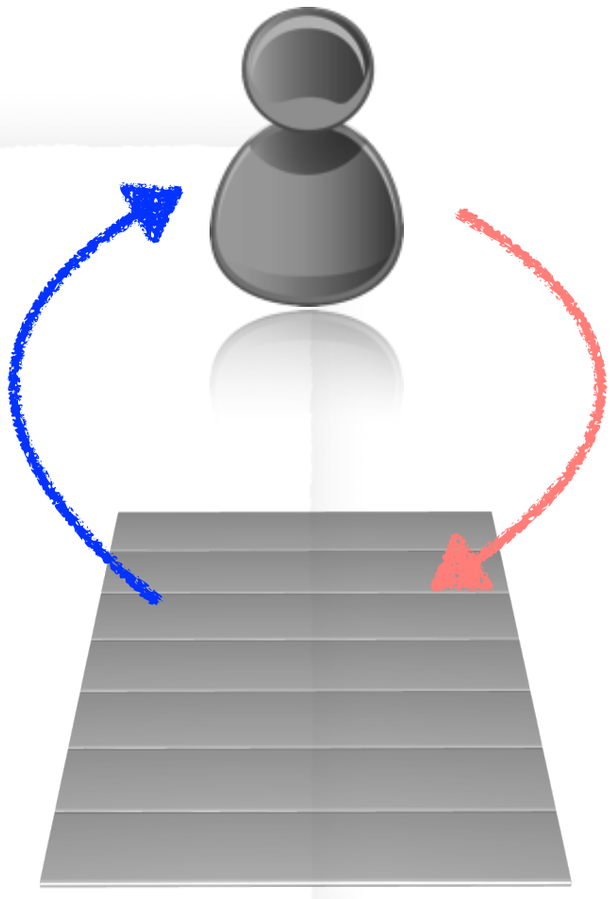


Figure 2.1 An agent in its environment. The agent takes sensory input from the environment, and produces as output actions that affect it. The interaction is usually an ongoing, non-terminating one.

What is an agent?

(Ferber, 95) names **agent** a **physical or virtual entity** which:

a. can **act** in its **environment**,

b. can **communicate** with other agents

c. has its own set of **individual objectives**

d. has its own **ressources**

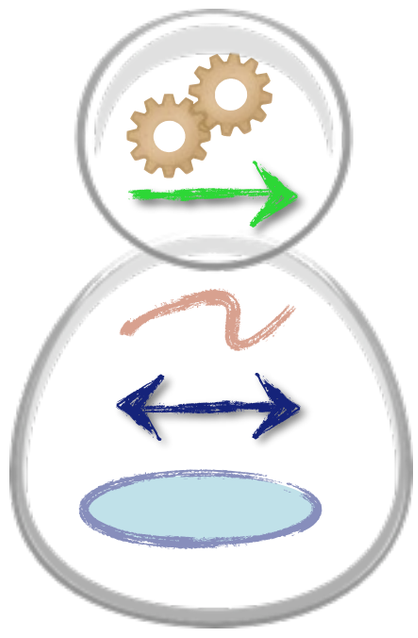
e. can **perceive** (**partially**) its environment

f. has a partial **representation** of its environment (or even no representation)

g. has **skills** and can **offer services**

h. can (eventually) reproduce

i. has a behavior tending to **satisfy its own objectives**, **taking into account** its ressources and skills, its perception, representations and communication it gets.



Agent

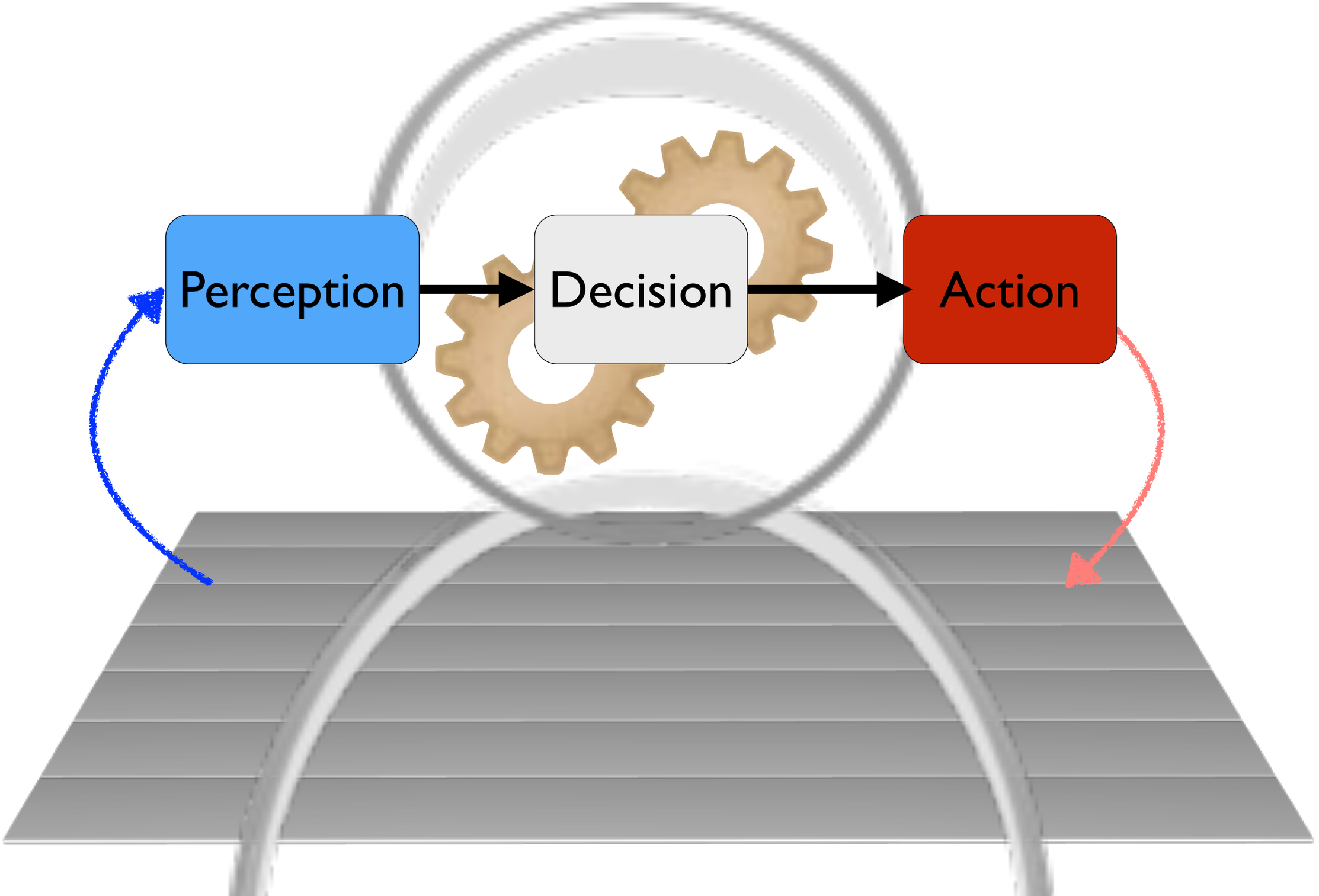
Decision-making
Behavior
Communication

Actions

Interactions

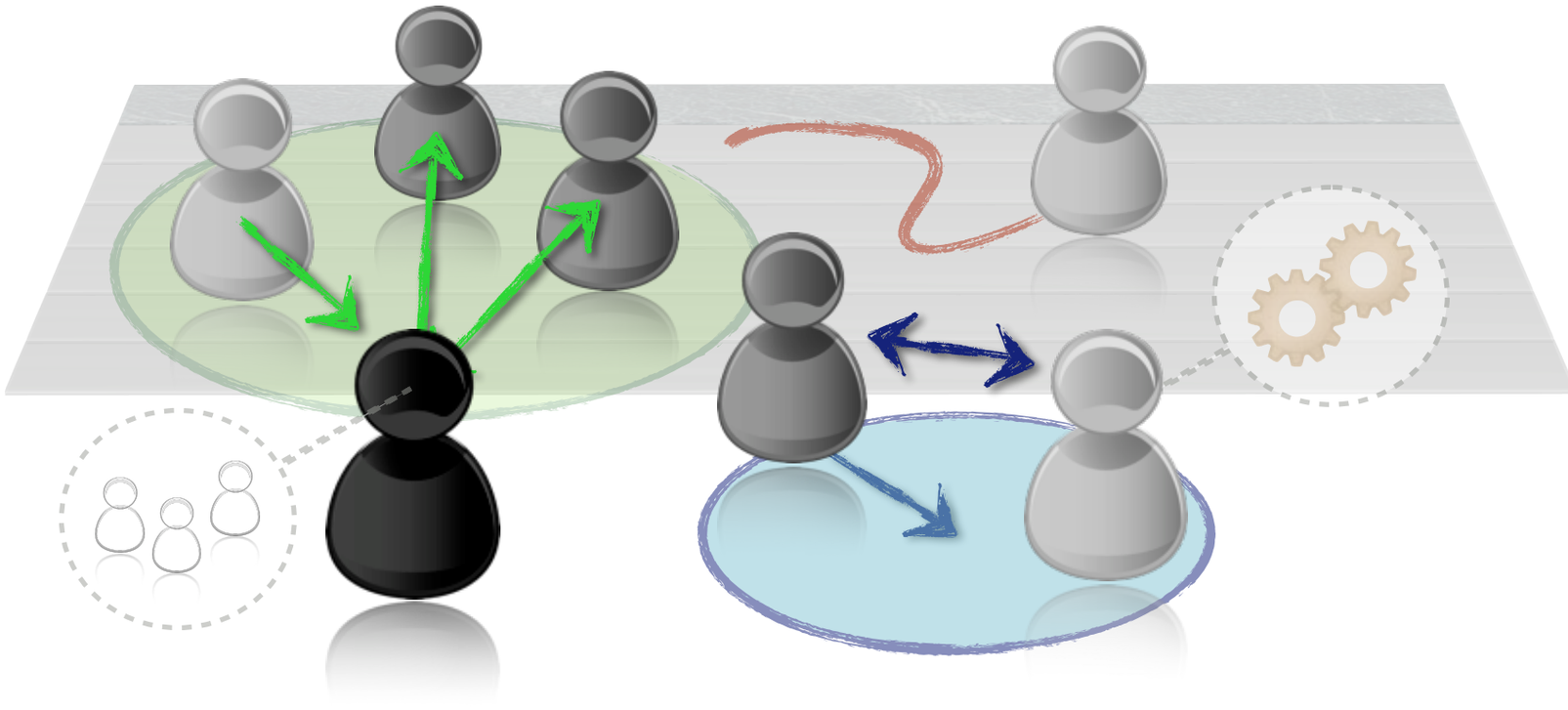
Perception

The basic agent life-cycle has 3 steps.
Agents can be reactive or cognitive depending on the decision complexity.



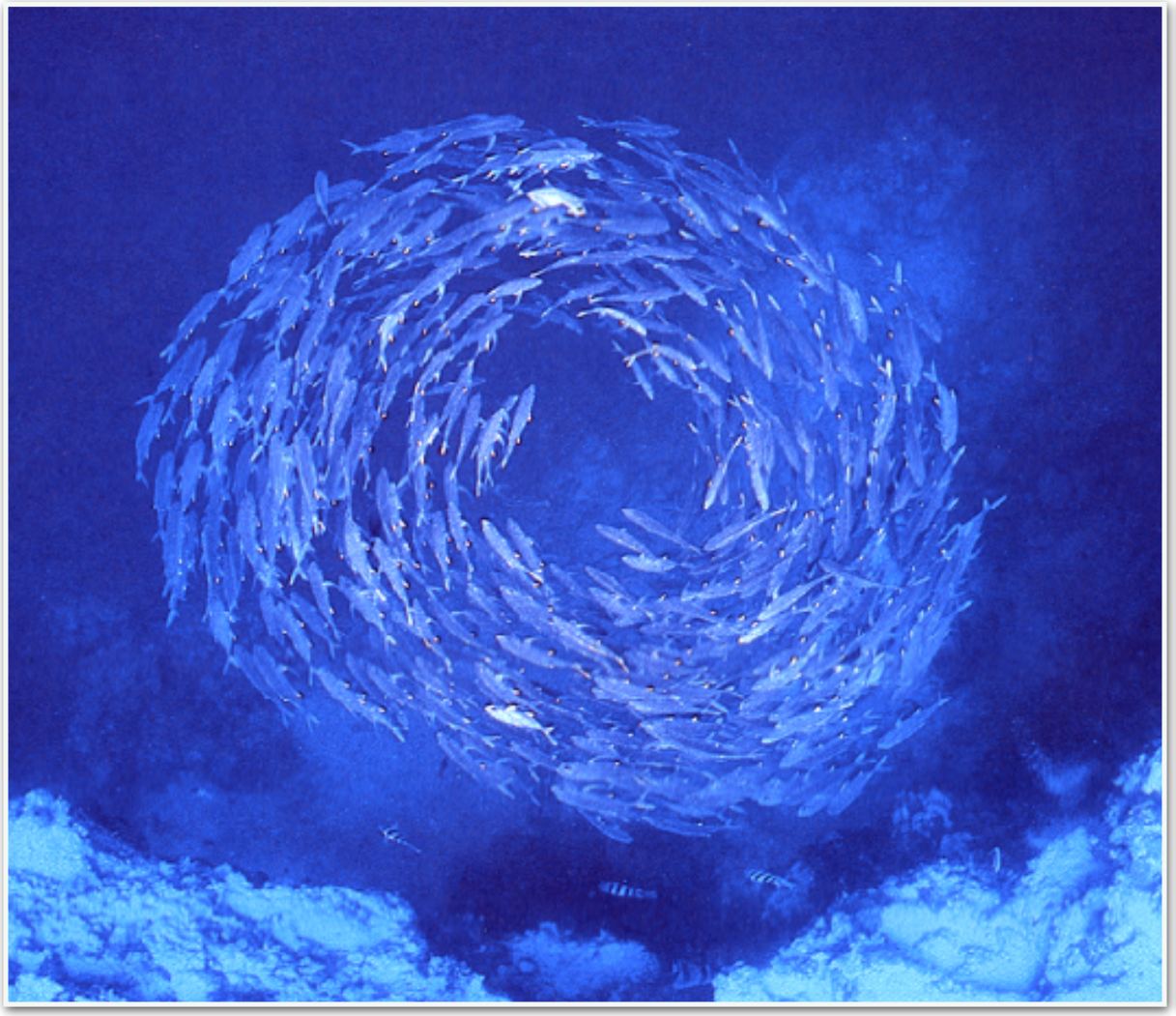
What is a Multi-Agent System ?

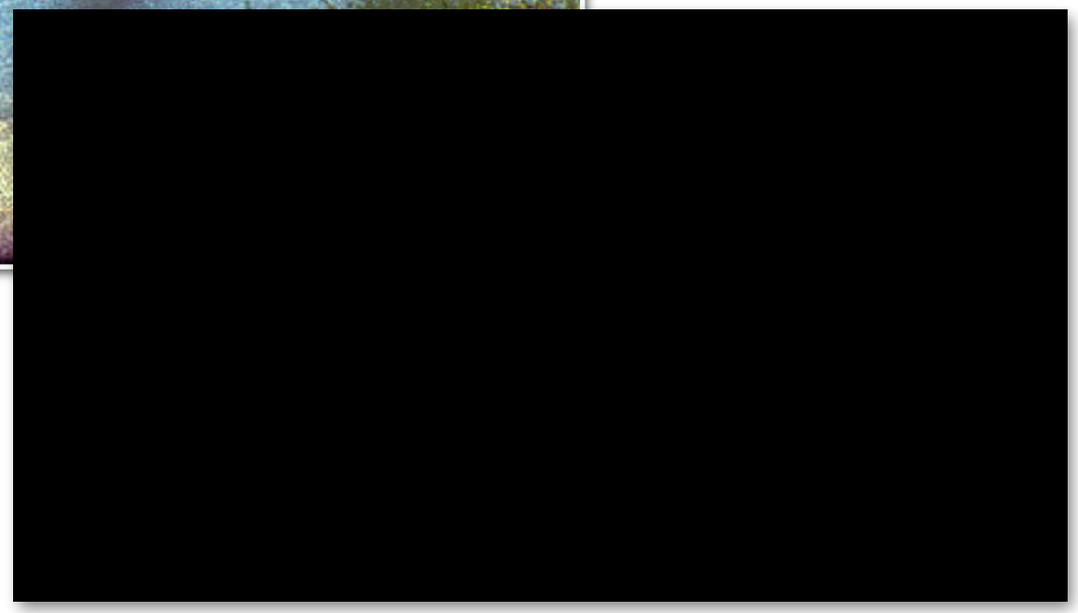
- A Multi-Agent System is a **set of agents acting and communicating in an environment.**



- In addition some authors add:
  Passive objects and **an organization or coordination mode.**

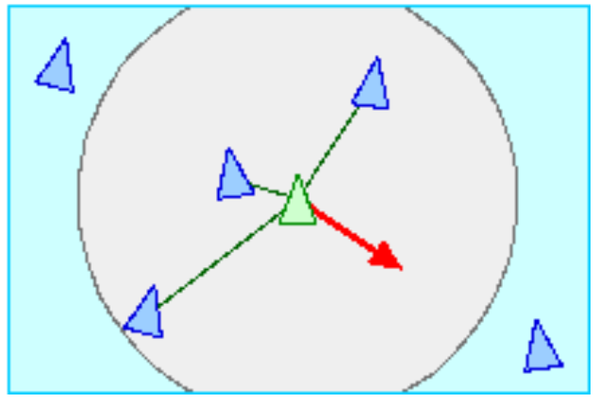
Example of reactive agents: Reynolds' Boids (Craig Reynolds (1987)



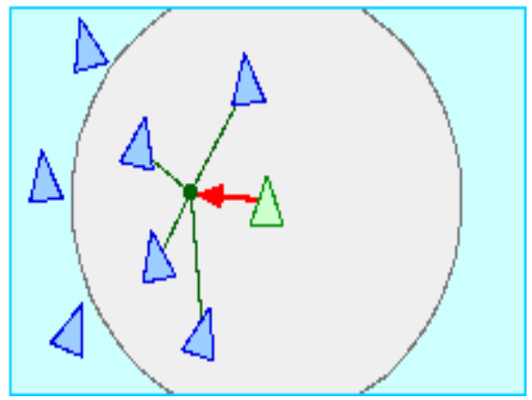


Boids: Interactions by field of forces

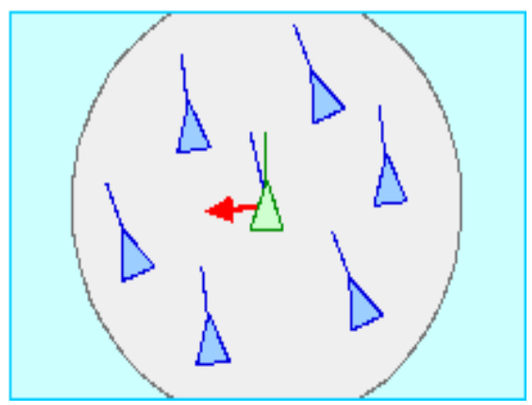
- **Separation**: the force is calculated so as to push back the Boid from its close neighbours.



- The purpose of **cohesion** is to bring the Boid closer to the gravity center of the group.



- The force of **alignment** is calculated as being an average between speeds of the neighbours.



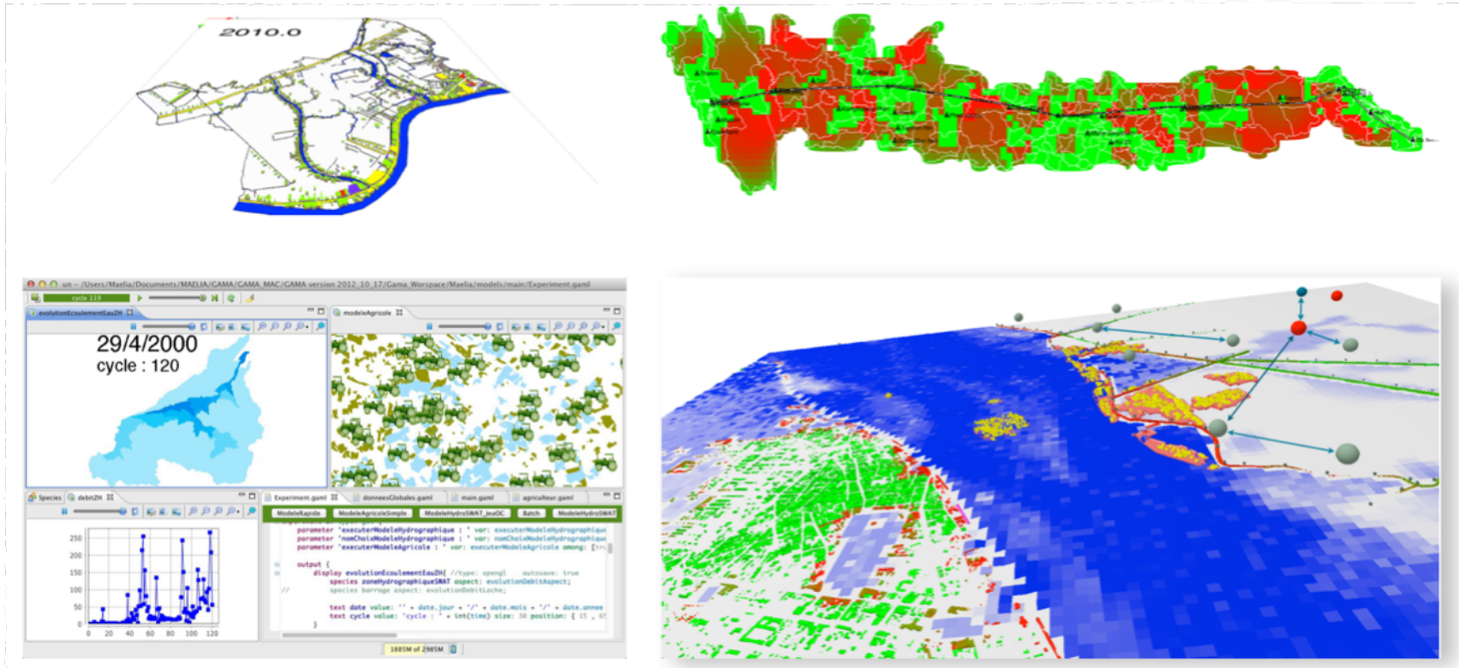
Such model is available in GAMA library.

Application: crowd animation (movie !)

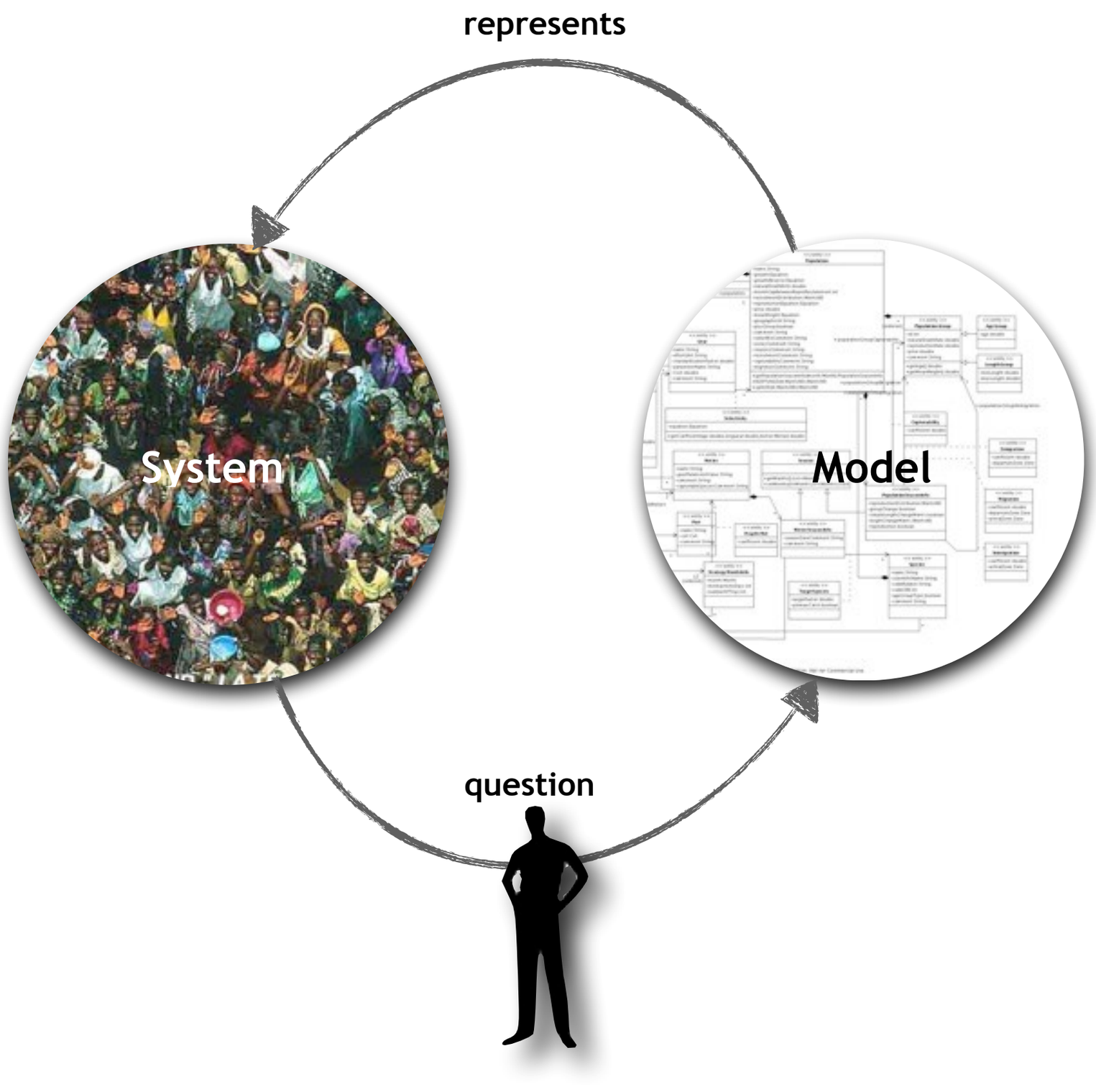
- Objective:
  short-term individual
  and collective realism

http://www.massivesoftware.com/index.html

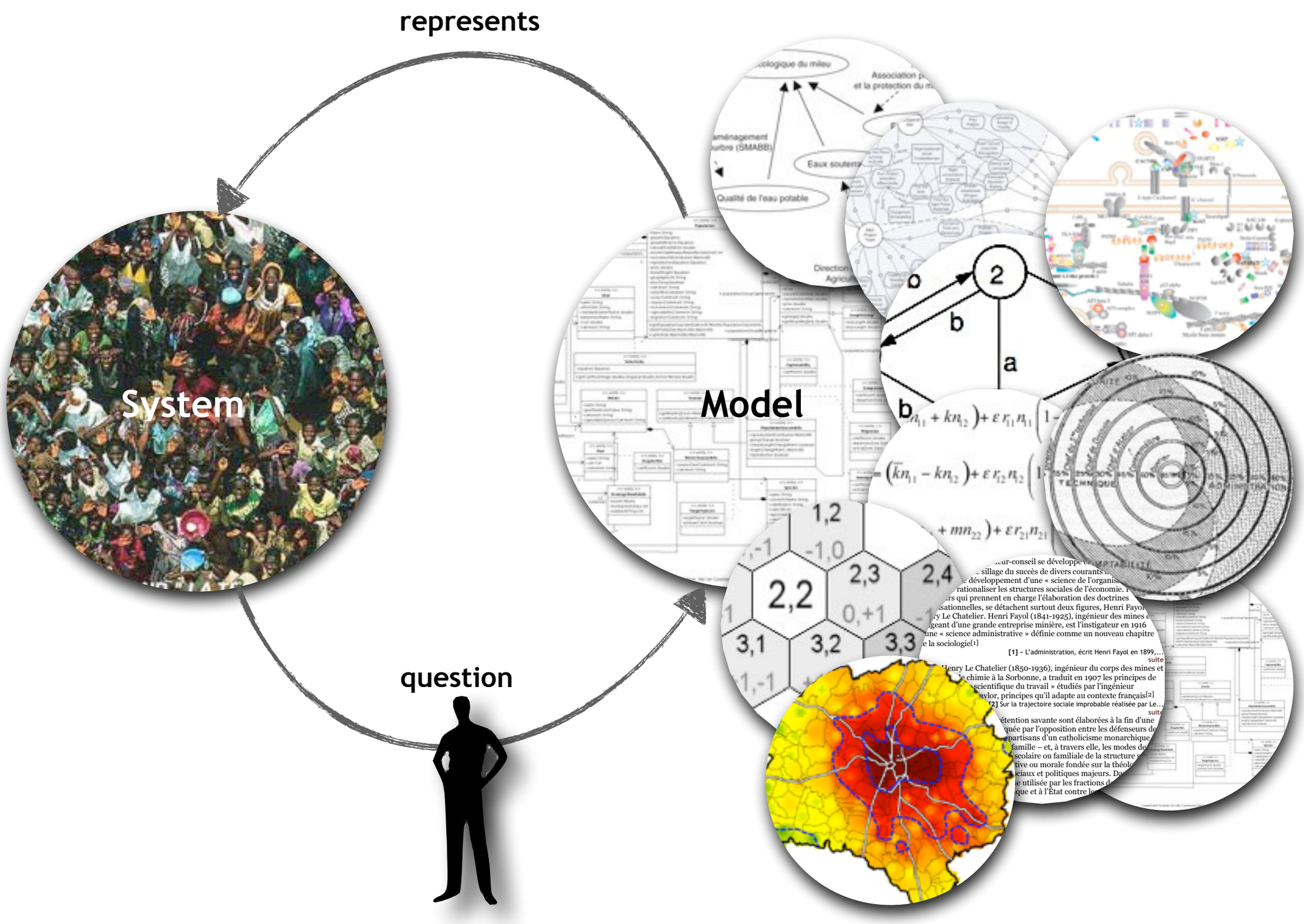
Agent-Based Modelling and Simulation



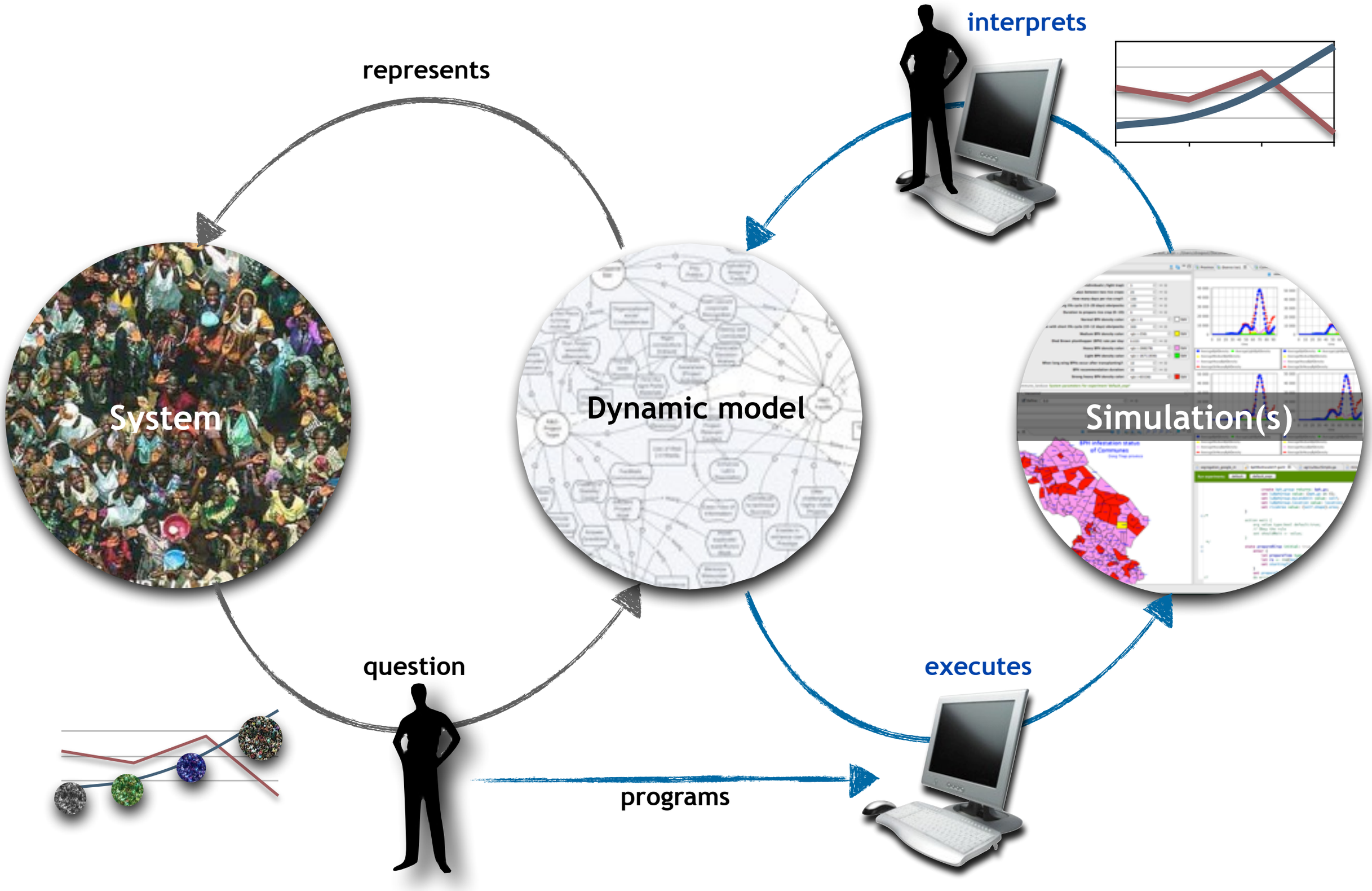
A model is a simplified representation of a reference system, designed to help answering a question on this system.



Representation can use multiple supports and languages, depending on the question, traditions...
They are specified by meta-models.

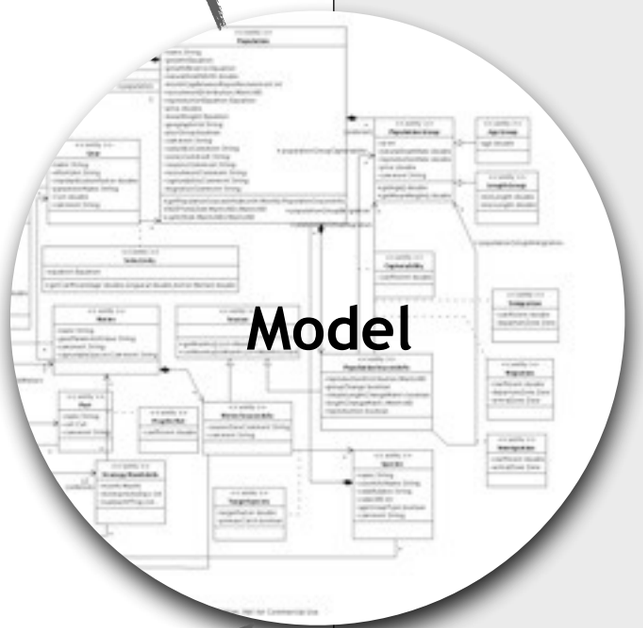


The execution of a (dynamic) computer model is called a simulation.



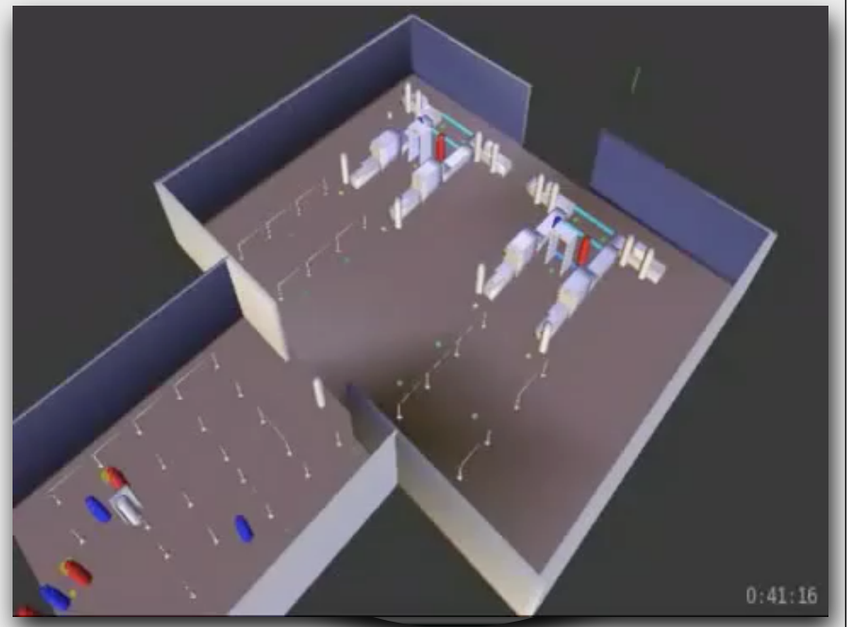
Uses of the simulation

represents



Uses

Validation,
Understanding,
Visualisation, Training,
Decision-Support System,
Prévision...

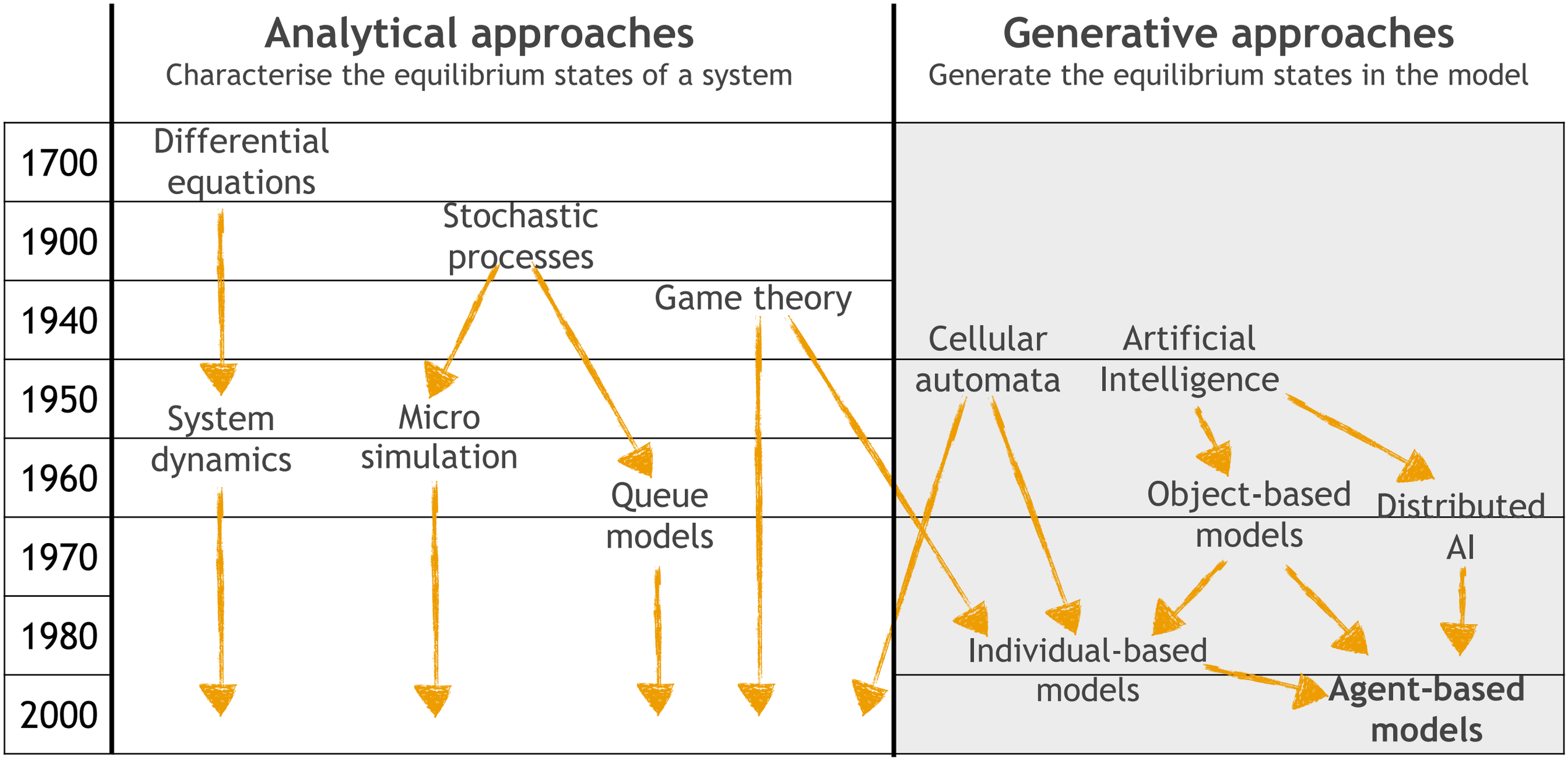


question

programs

executes

Dynamic models and simulations meta-models have a long history

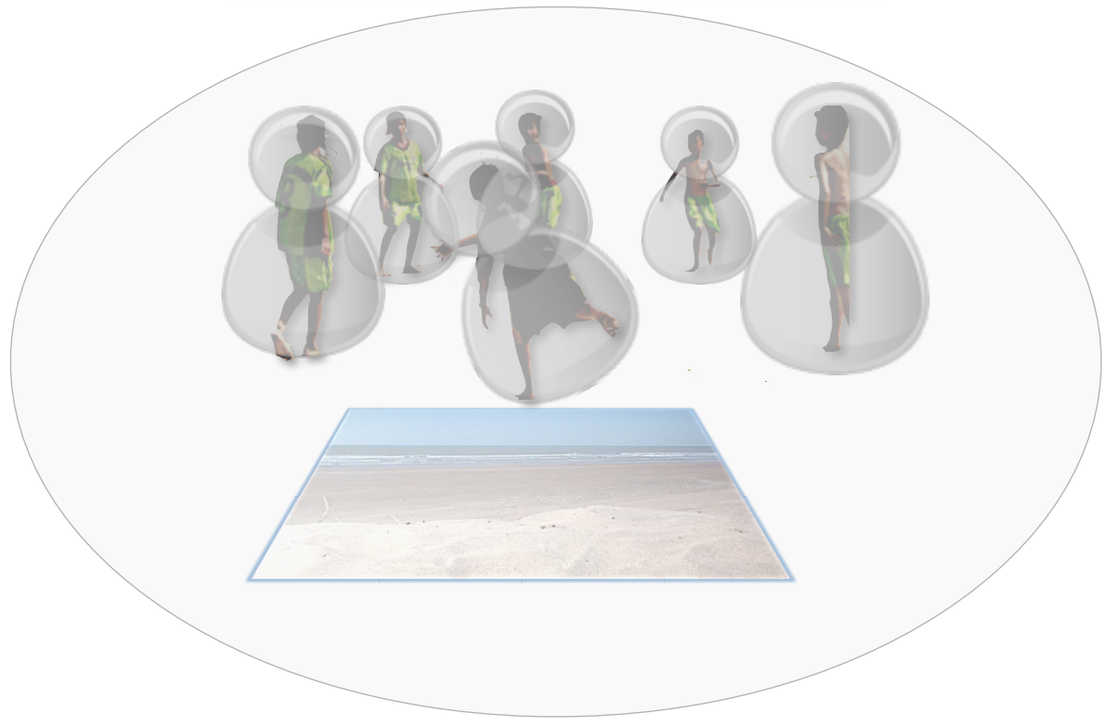


(adapted by Alexis Drogoul from Troitzsch & Gilbert 2001)

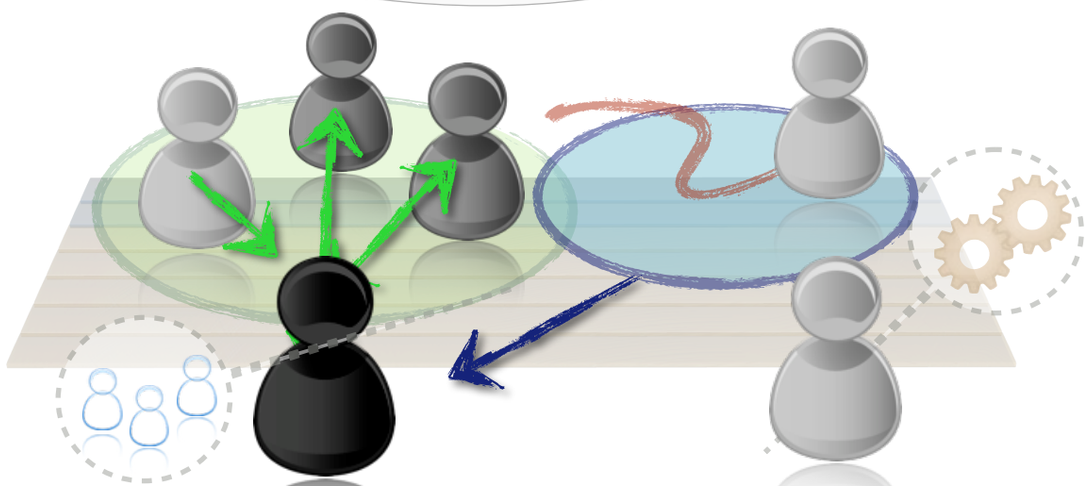
Agent-based models rely on a form of individual-based (1 to 1) representation.

Reference system

represents

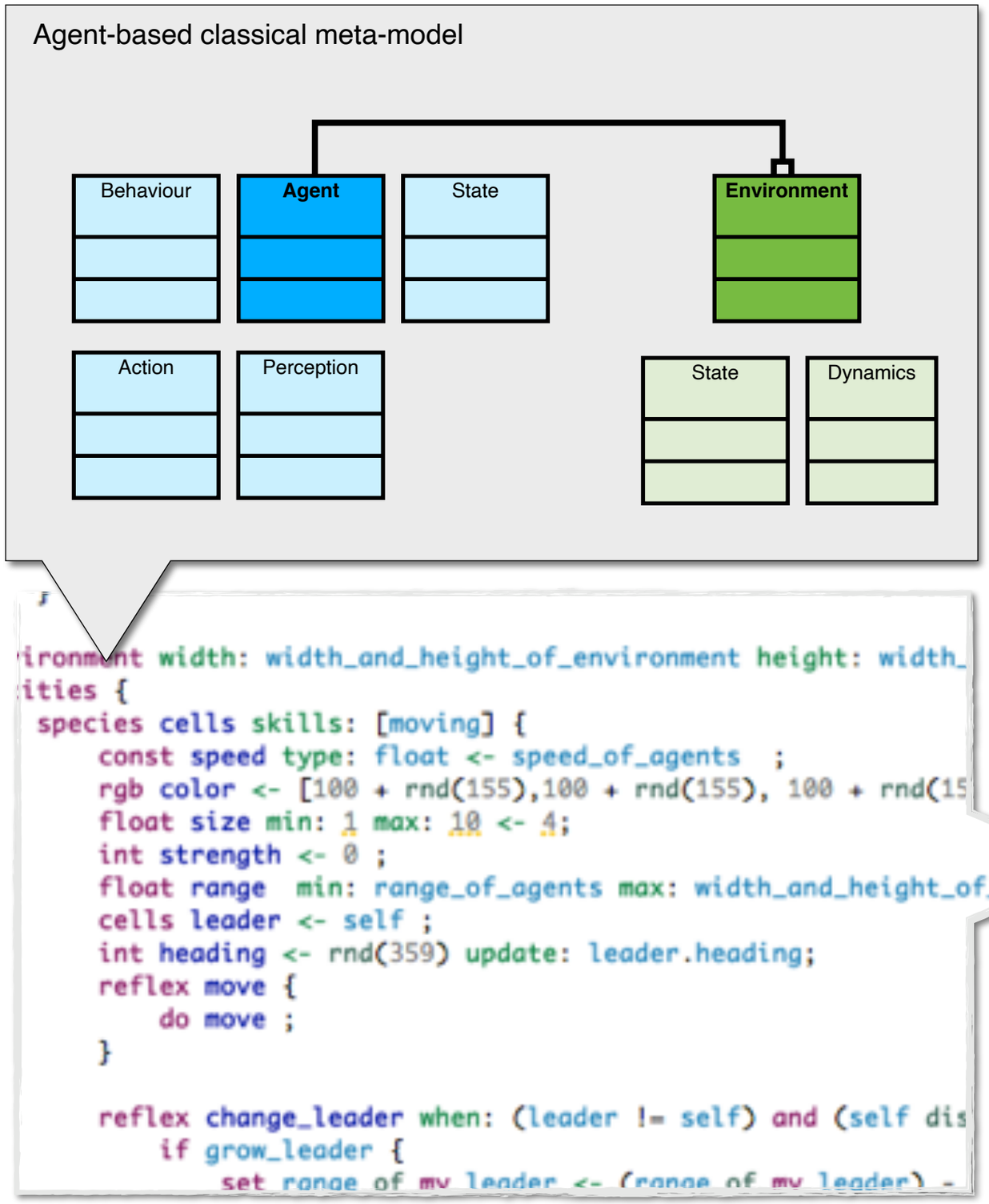


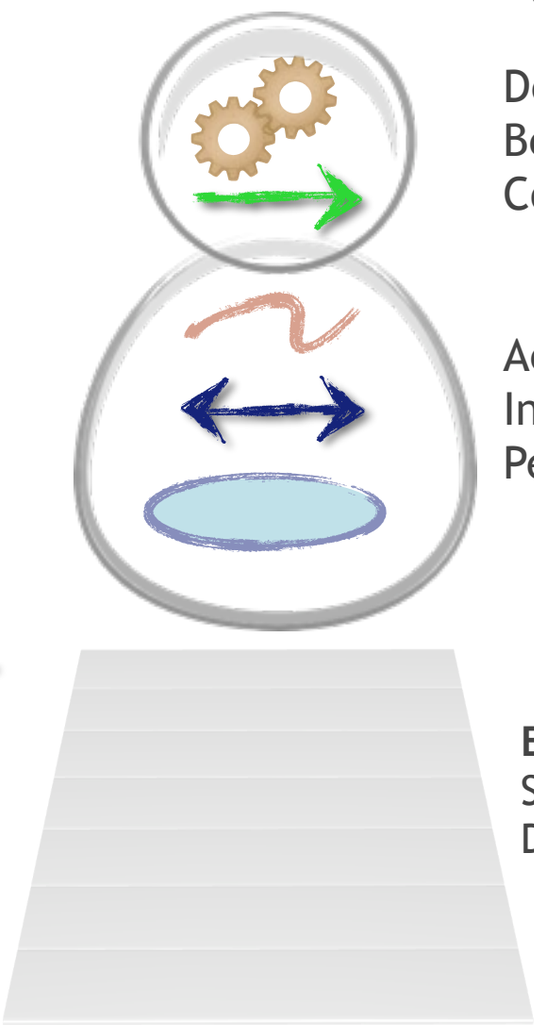
Modeling



Agent-based model

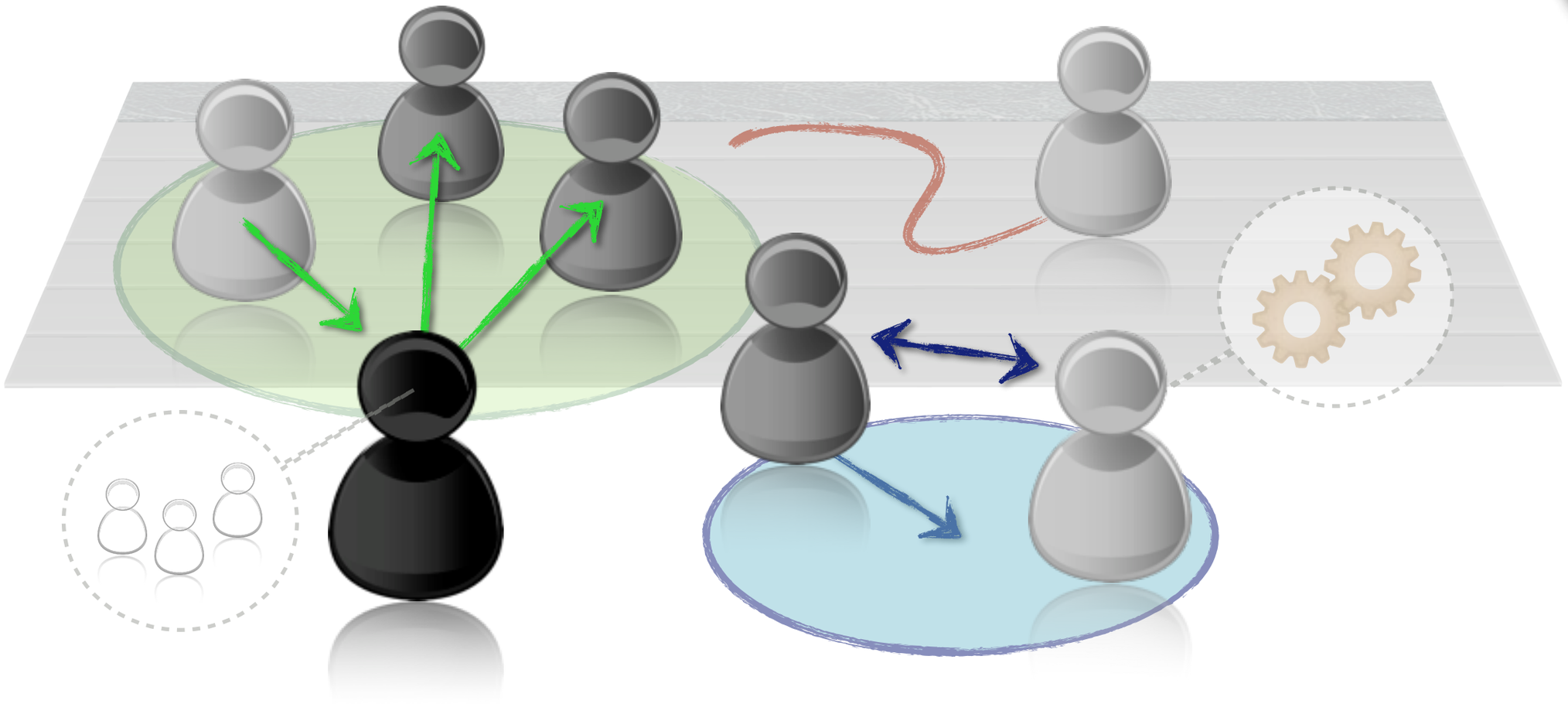
Agent-based models are written using a few key concepts





The agents and their environment constitute a virtual «micro-world» that can be experimented like a real system (with more freedom)

Time



Environment

Illustration: road traffic

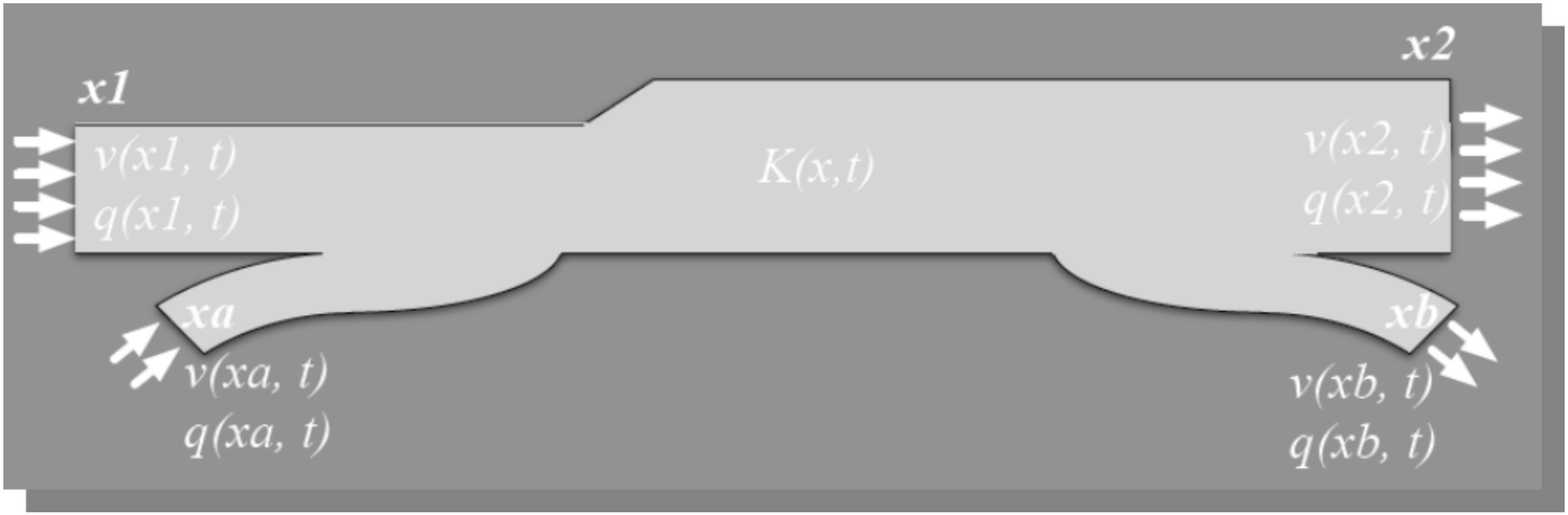
- Traffic jams, delays
  - How to understand them?
  - How to anticipate them?
  - How to control them?
- Difficulties
  - « Experiments » are difficult
  - Reproduction is impossible
- Simulation is the only way

Classical macroscopic models

$$\begin{cases} Q(\Delta x, \Delta t) = K(\Delta x, t) V(\Delta x, \Delta t) \\ V(\Delta x, \Delta t) = V_e\left(K(\Delta x, t)\right) \\ \dfrac{\partial Q(\Delta x, \Delta t)}{\partial x} + \dfrac{\partial K(\Delta x, t)}{\partial t} = 0 \end{cases}$$

LWR macroscopic model

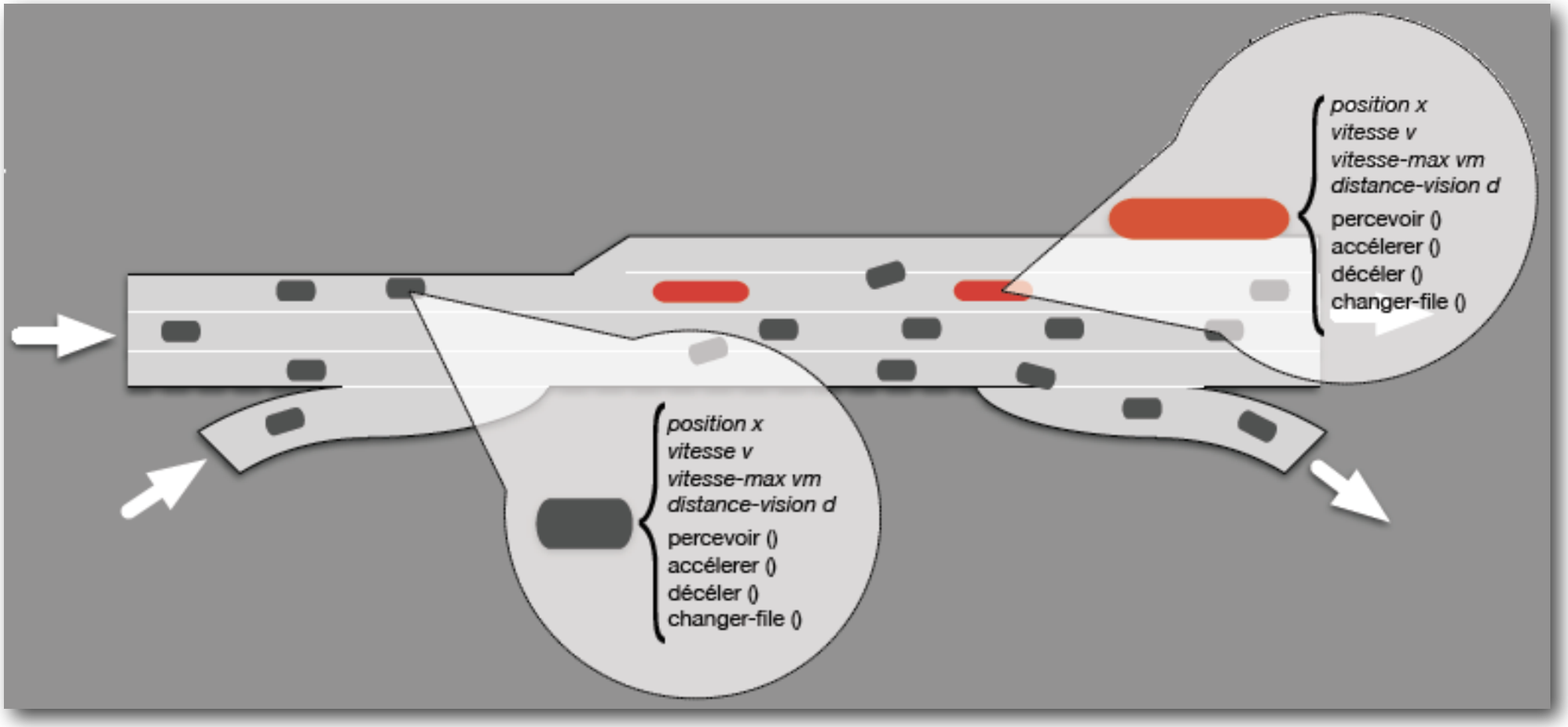
- based on a (physical) analogy between the flow of traffic and the flow of a fluid in a pipe.



- Flow of vehicles characterised by macroscopic attributes, behaviours averaged in global equations.

Agent-based models

- Attributes and behaviours (ou equations, rules …) are "attached" to individuals.

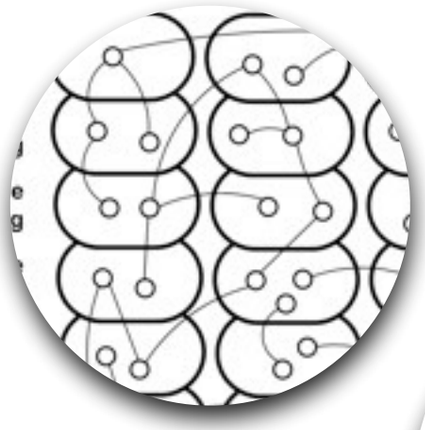


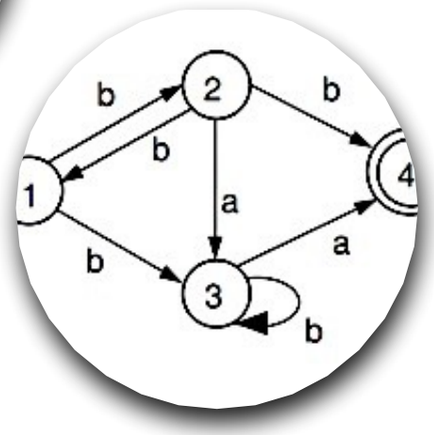
- Allow for heterogeneous vehicles and behaviours and stochasticity.
- Analytical results impossible to obtain: simulation is the only possibility.

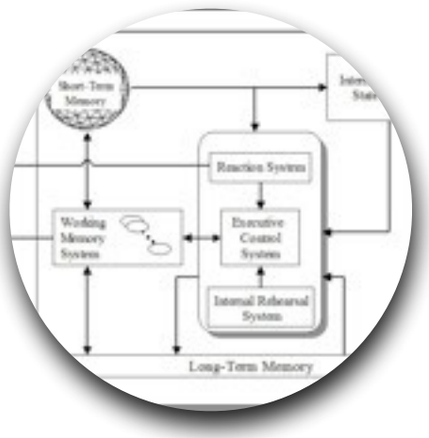
Agent-based models are versatile and heterogeneous: agents can represent any object or aggregation of objects of the reference system.

SimPop model
http://www.simpop.parisgeo.cnrs.fr/

Agent-based models are agnostic : agents can be programmed using any language or decision-making architecture

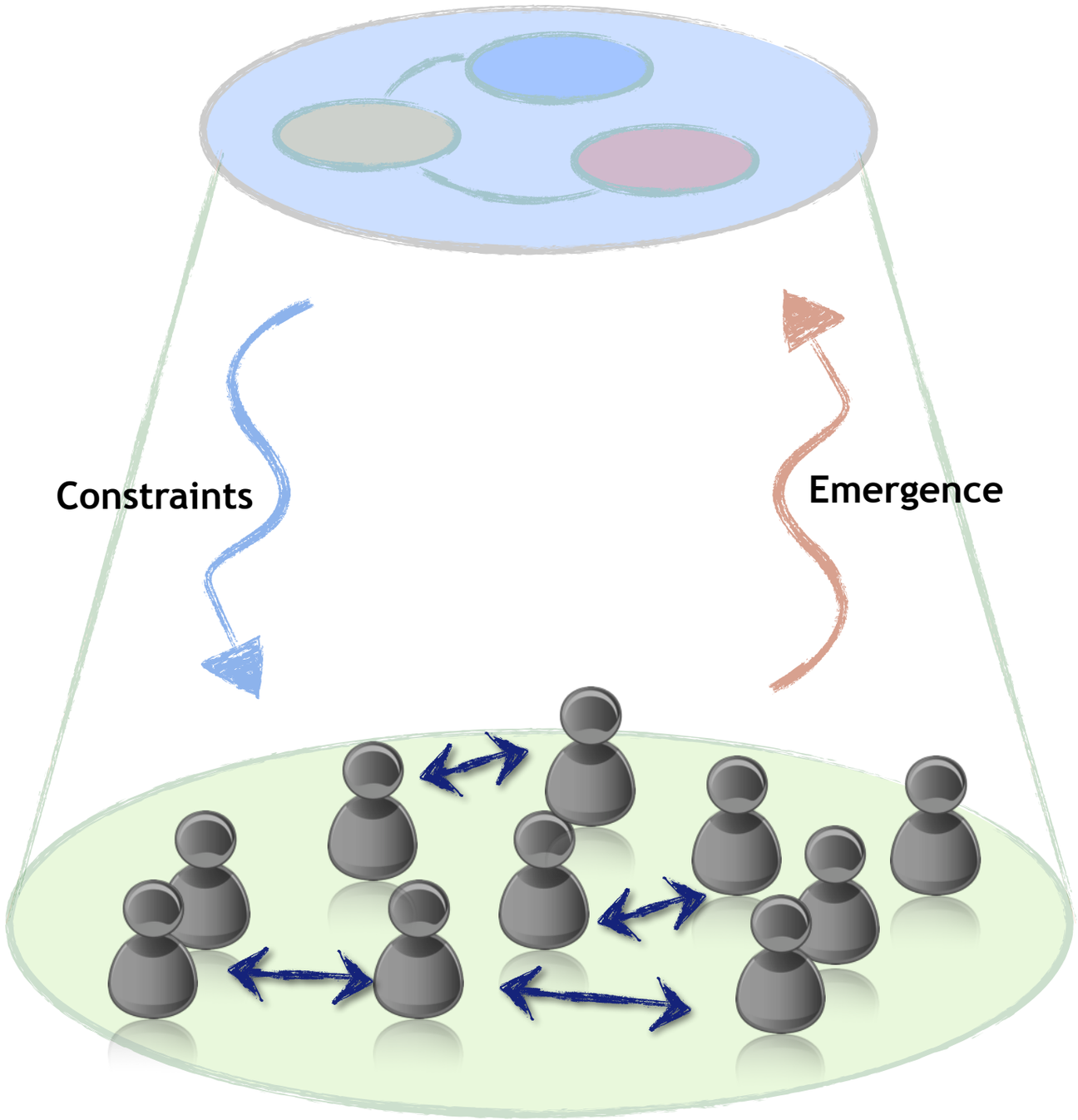






- Any computer program
- Expert systems
- Finite state automata
- Task-based architectures
- Perception-decision-action architectures
- Planning architectures
- Neural networks
- Bayesian networks...

Agent-based models are <u>generative</u>: they represent behaviours at a «micro-level» and generate outcomes, with simulations, at a «macro-level».



Macro-level
(simulation/observation level)

Micro-level
(modeling/description level)

Agent-based models are well adapted to situations where...

1. it is difficult to test hypotheses solely based on observations of the reference system
2. the actors of a reference system are **heterogeneous**
3. it is possible to identify intermediary **levels**/organisations that influence the dynamics of the reference system
4. the **level of analysis/observation** is not fixed
5. changes at the macro-level should be outcomes, and not inputs, of the model

- **As such, they represent an invaluable tool for building models of complex systems**

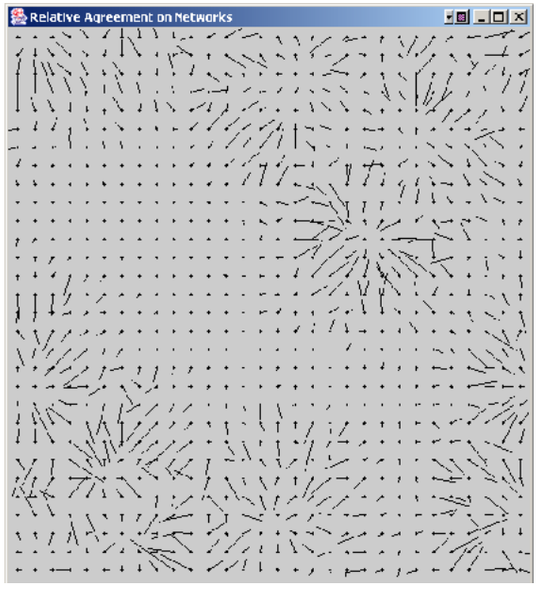
Some remarks concerning Agent-Based Modelling

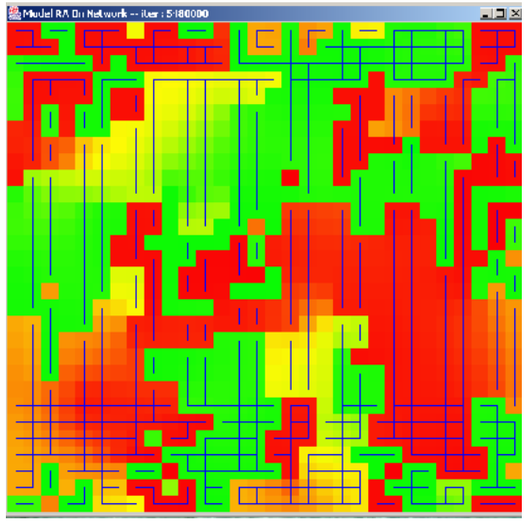
- **Advantages**
  - Hypotheses expressed at the individual level
  - Modelling the dynamics
  - Models are experimental objects (simulation)

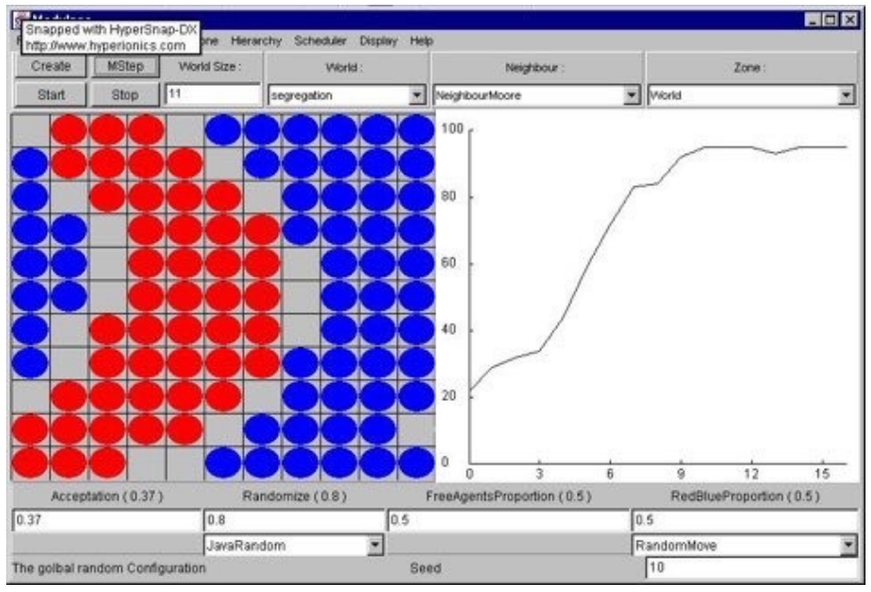
- **Drawbacks**
  - Reproduction of the complexity of the real system (micro/macro link)
  - Difficulty to understand how the results are produced
  - Validation

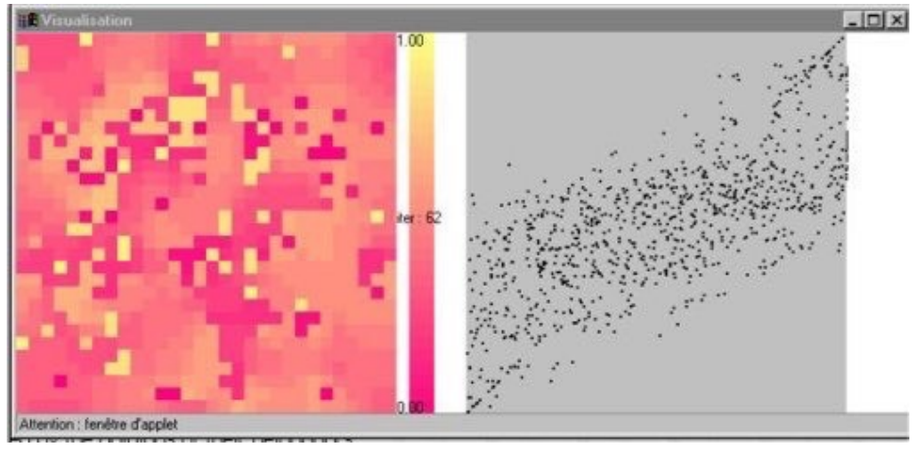
Use of modelling

- **To understand**
  - Test/elaboration of hypotheses, prospective simulation
  - Formalization/verification of sociological theories



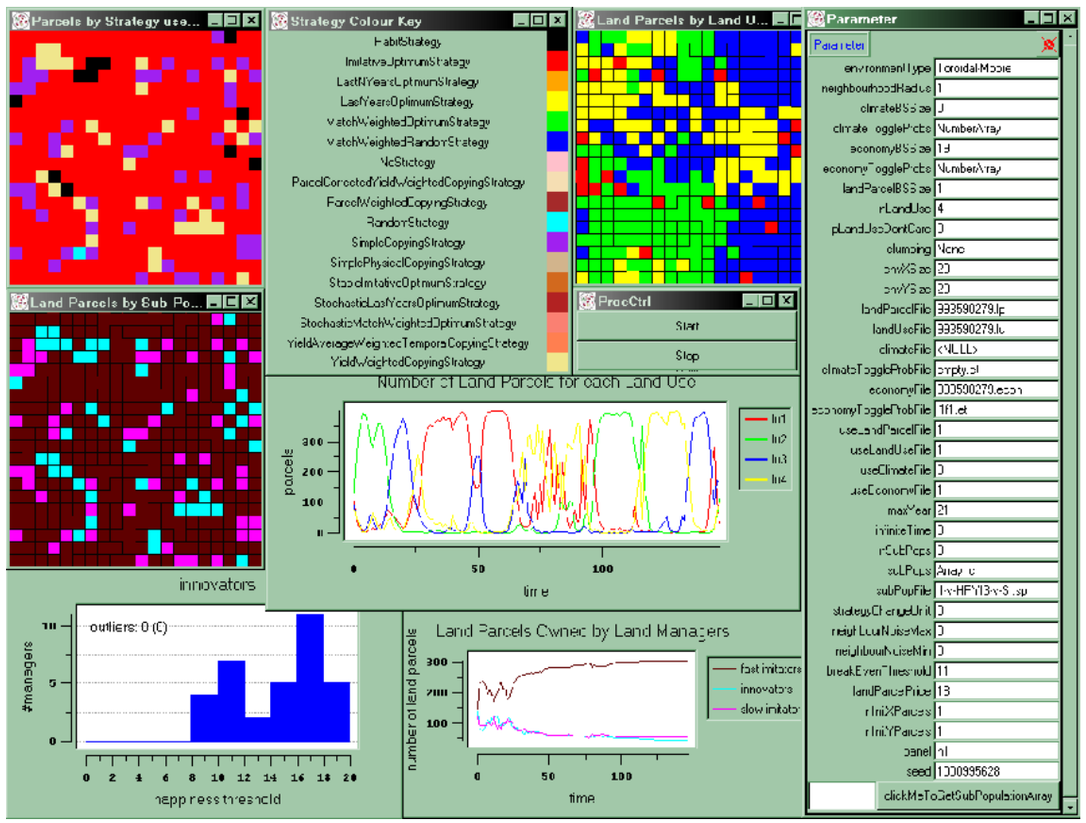






Use of modelling

- To understand
- **To decide**
  - Predictive simulation for decision-making
  - Test of scenarios through simulation
  - Artefacts for helping negotiation and/or coordinated management



Use of modelling

- To understand
- To decide
- **Interactive simulation**
  - « Serious » Gaming (SimCity)
  - Training, teaching

Rebuild phenomena to understand them

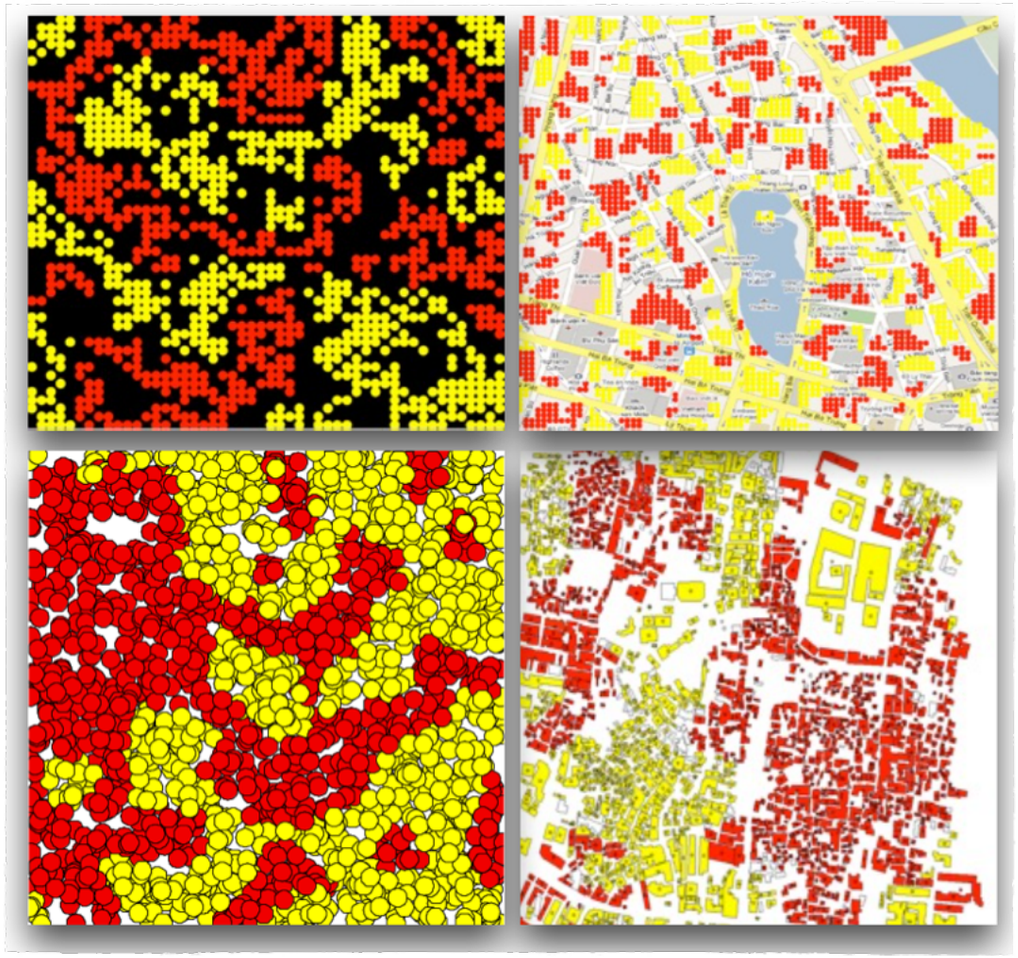
- Use Modelling not Models !!!

- **Rebuilding phenomena enable to better understand them**
  - Pappert (Logo), Resnick (NetLogo)

- What could be the individual behaviours producing a given collective phenomenon?
  - Experimental approach by trial and errors
  - ex: Regroupment of ants dead bodies outside of the anthill

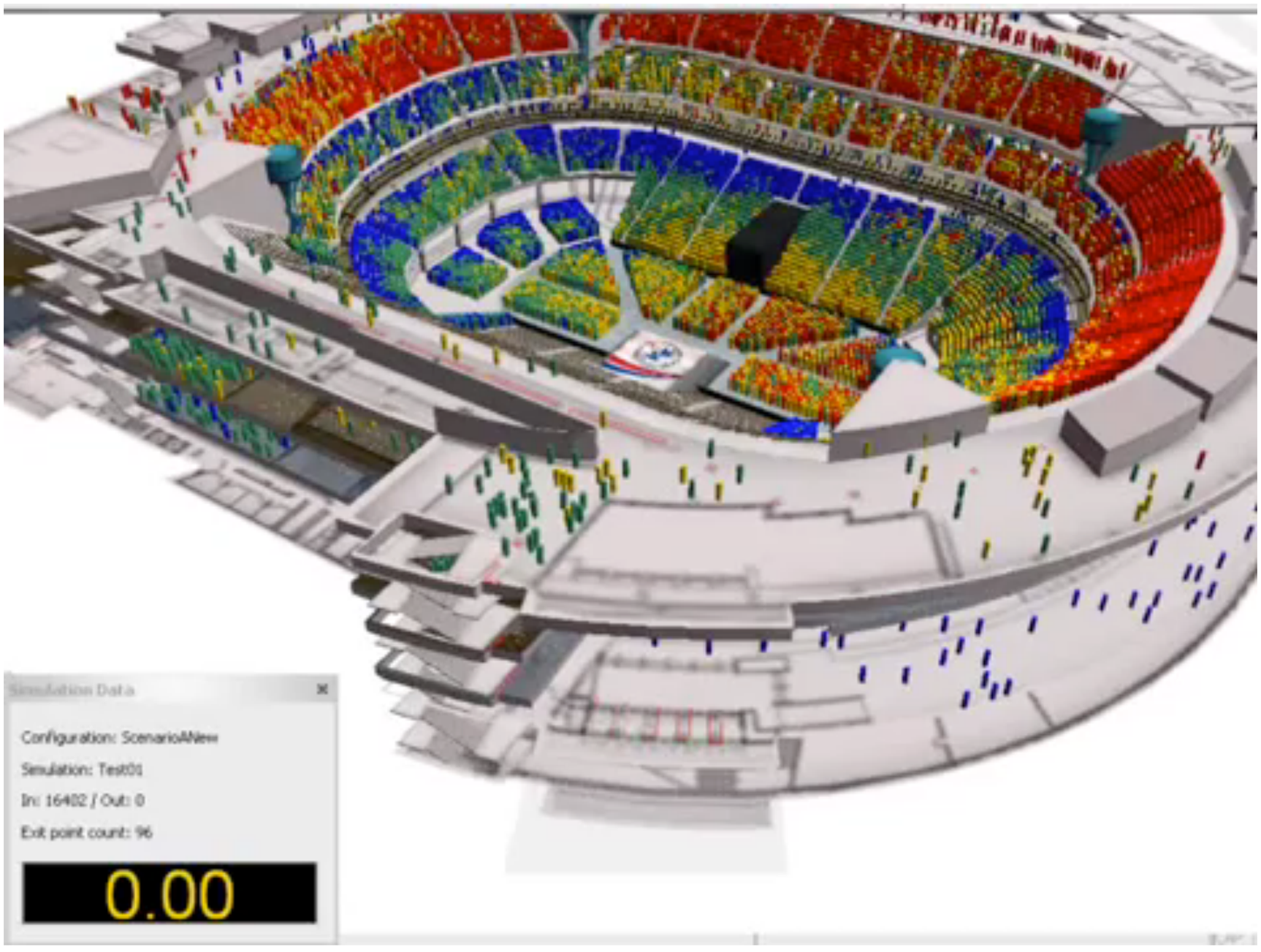
Agent-Based Modelling and Simulation

Some examples



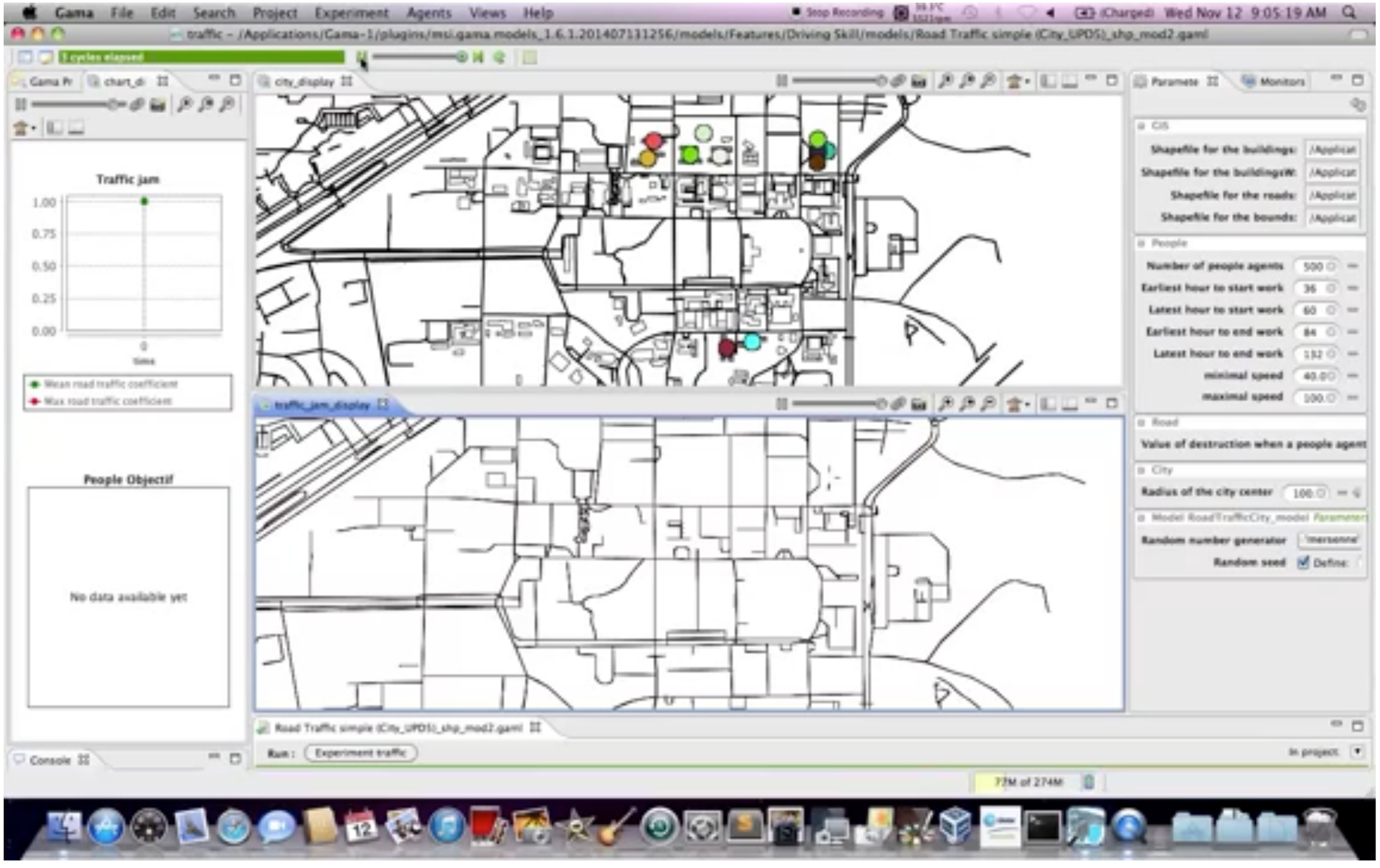
Crowd dynamics

Evacuation


Simulation Data
Configuration: ScenarioANew
Simulation: Test01
In: 16402 / Out: 0
Exit point count: 96
0.00

Epidemics

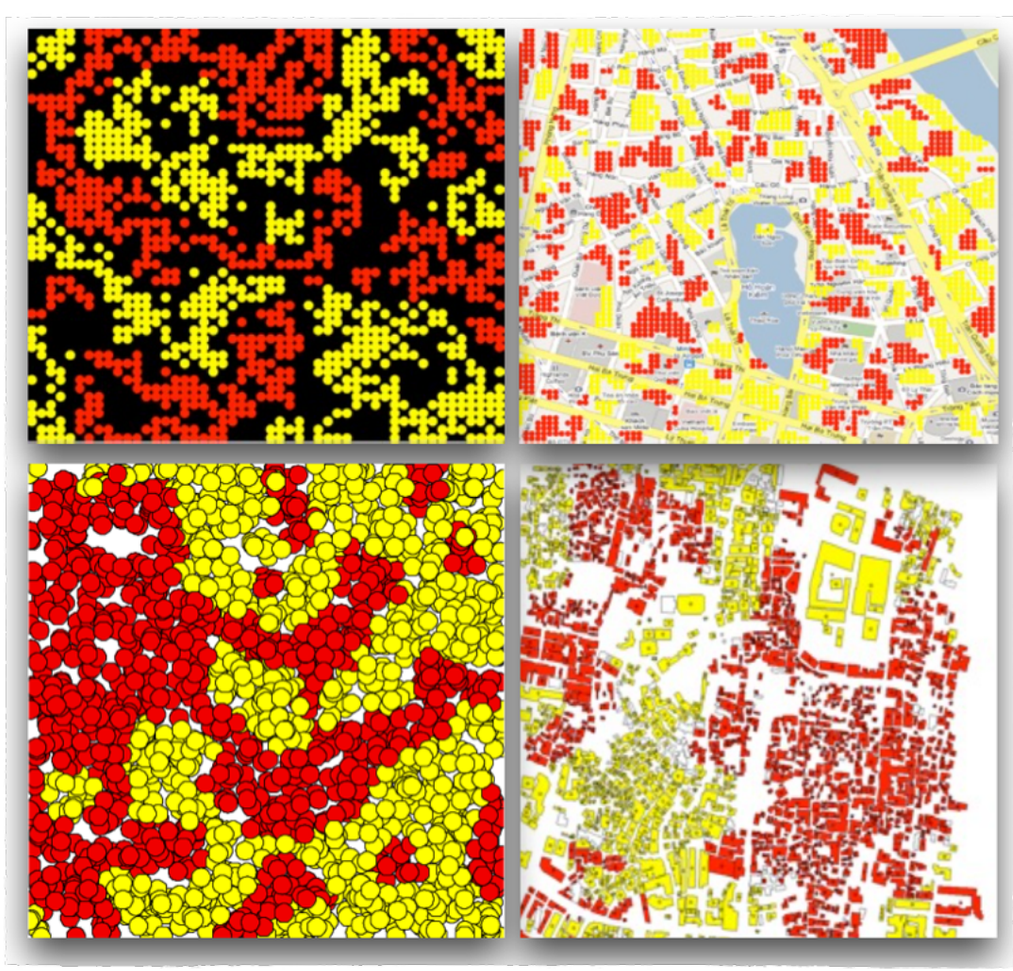
Traffic


Gama File Edit Search Project Experiment Agents Views Help
traffic - /Applications/Gama-1/plugins/msi.gama.models_1.6.1.201407131256/models/Features/Driving Skill/models/Road Traffic simple (City_UPDS)_shp_mod2.gaml
Traffic jam
Mean road traffic coefficient
Max road traffic coefficient
People Objectif
No data available yet
Shapefile for the buildings:
Shapefile for the buildingsW:
Shapefile for the roads:
Shapefile for the bounds:
Number of people agents
Earliest hour to start work
Latest hour to start work
Earliest hour to end work
Latest hour to end work
minimal speed
maximal speed
Radius of the city center
Random number generator
Random seed
Run :
Experiment traffic

Agent-Based Modelling and Simulation

The Schelling model

(a.k.a. the HelloWorld of the social simulation)

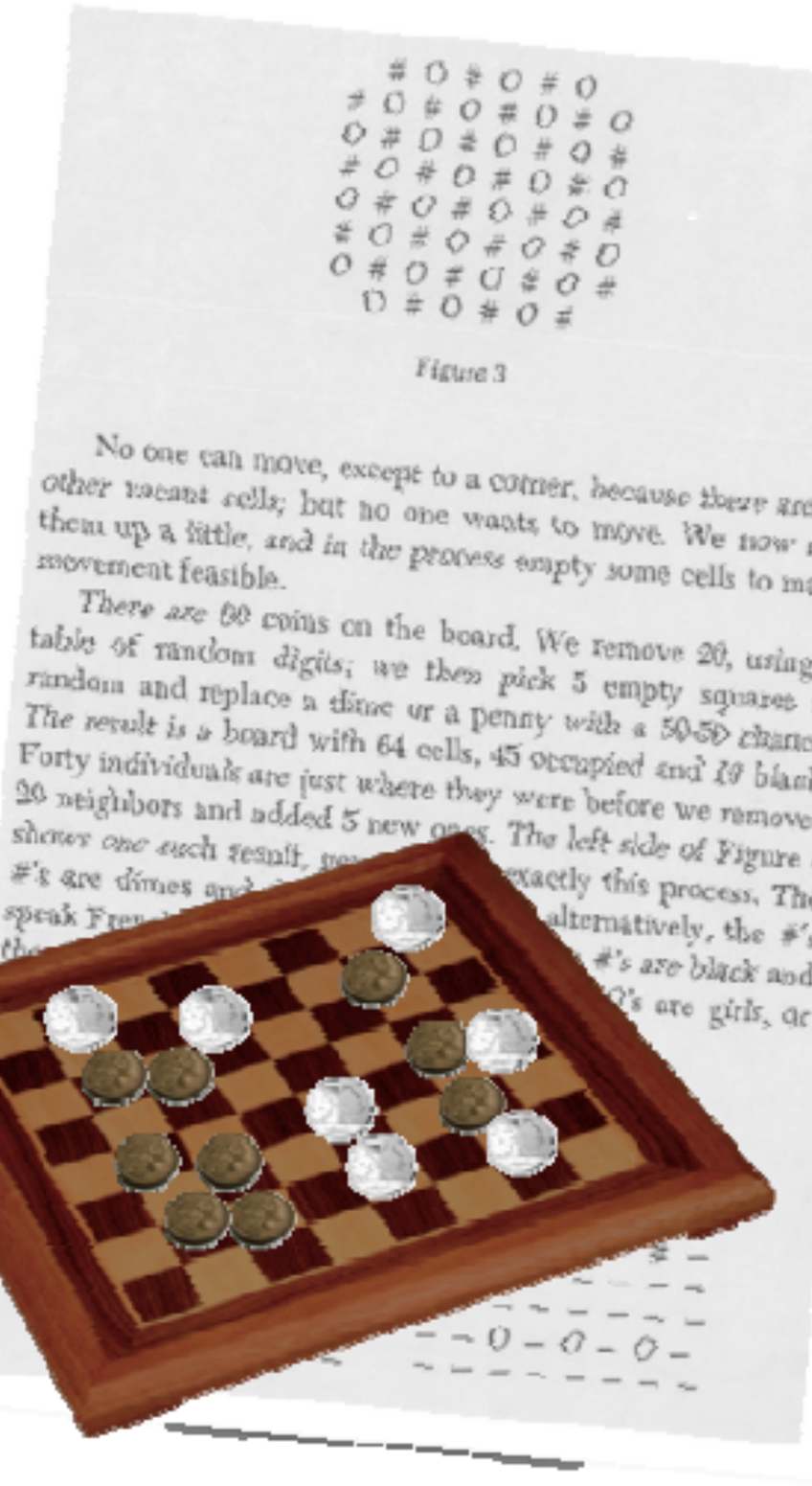


Segregation Model proposed by Schelling

- In 1969, Schelling introduced a model of segregation in which individuals of two different colours, positioned on a grid abstract representation of a district), choose where to live based on a preferred percentage of neighbours of the same color.

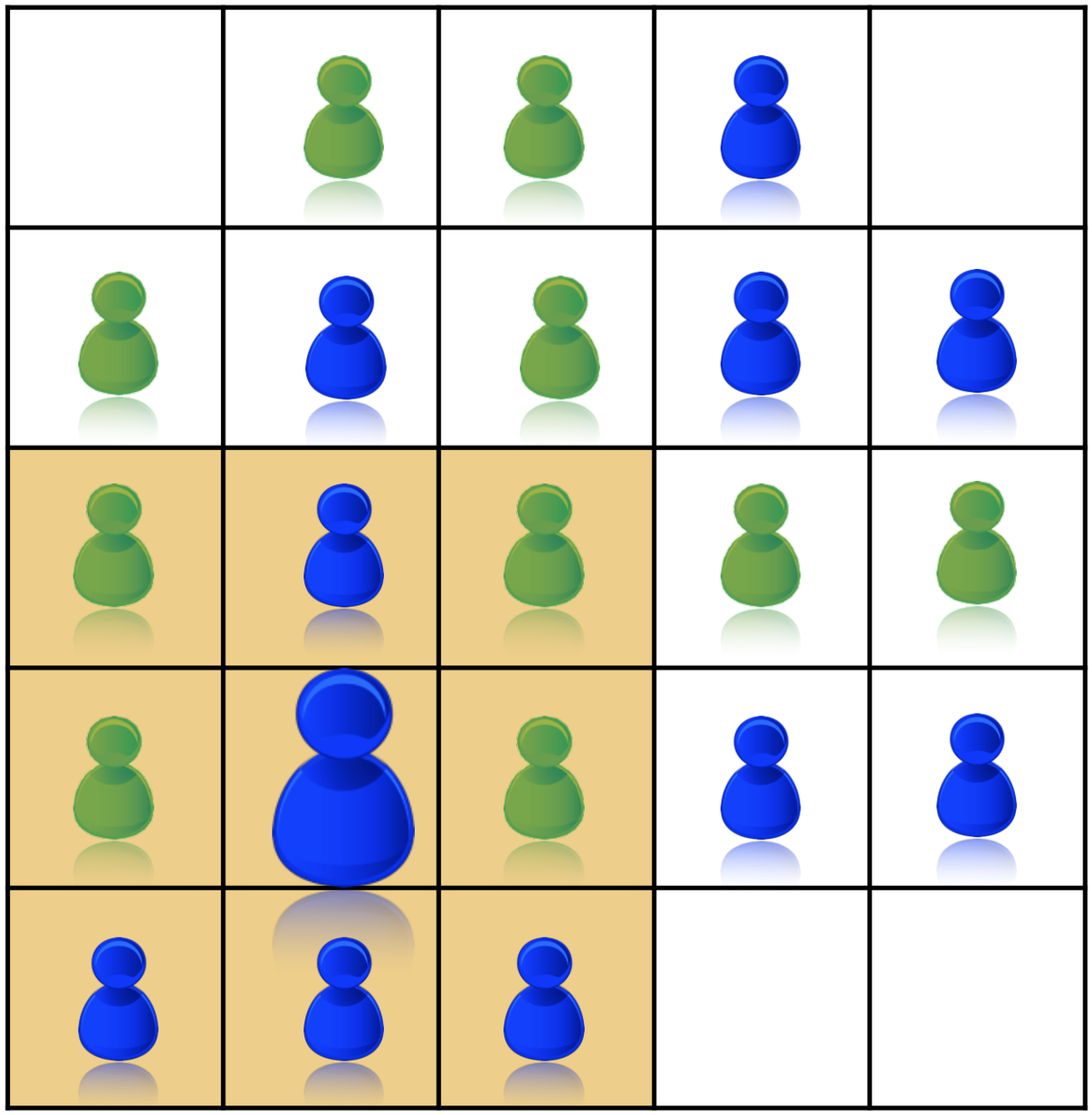
- Using coins on a board, he showed that a small preference for one's neighbours to be of the same color could lead to total segregation.

- It is a good example of a **generative model**, where the emergence of a phenomenon (here, segregation) is not directly predictable from the knowledge of individual.



Description

- In a simple agent-based model, agents are located in a discrete environment (grid). Each agent has a color, a perception of its neighbours and a **preference**: the minimal rate of neighbours of the same color that the agent can accept.

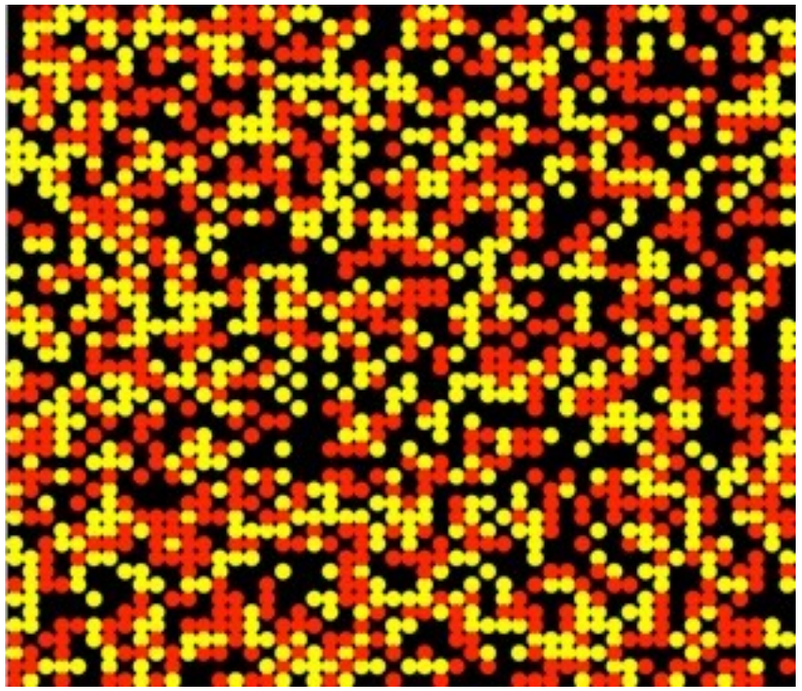


- **One behaviour**: if the rate of neighbours with the same color as the agent is lower than the agent preference, then it moves to another random free cell.

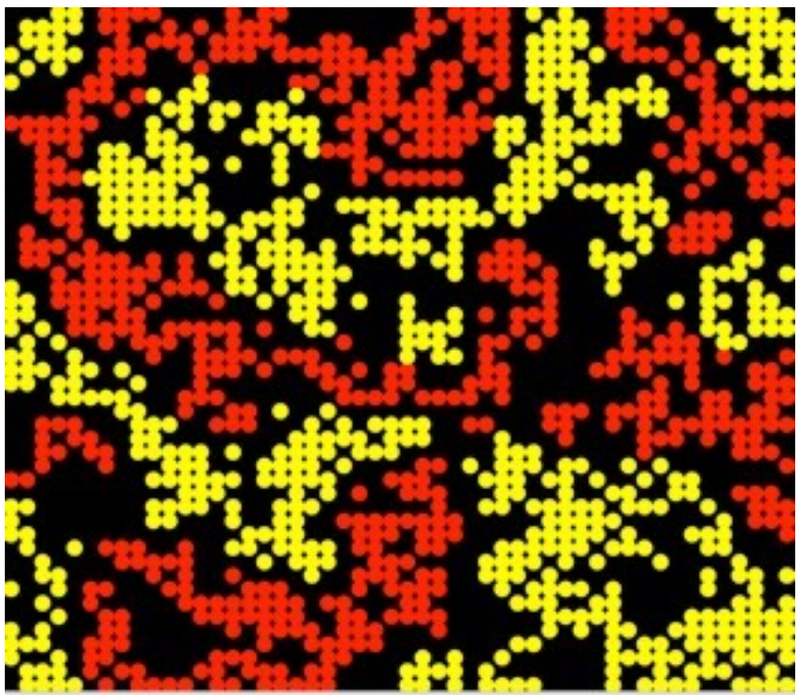
Results

- The main result shows that, even with a low individual preference (35%), 2 groups can be fully segregated.

- This phenomenon cannot be deduced analytically from the knowledge of individual preferences.



Initial situation
Grid : 50 x 50
1200 agents
Individual preference: 35%
Segregation index:
(∑similar neighbours/∑ neighbours)
: 49,9 %



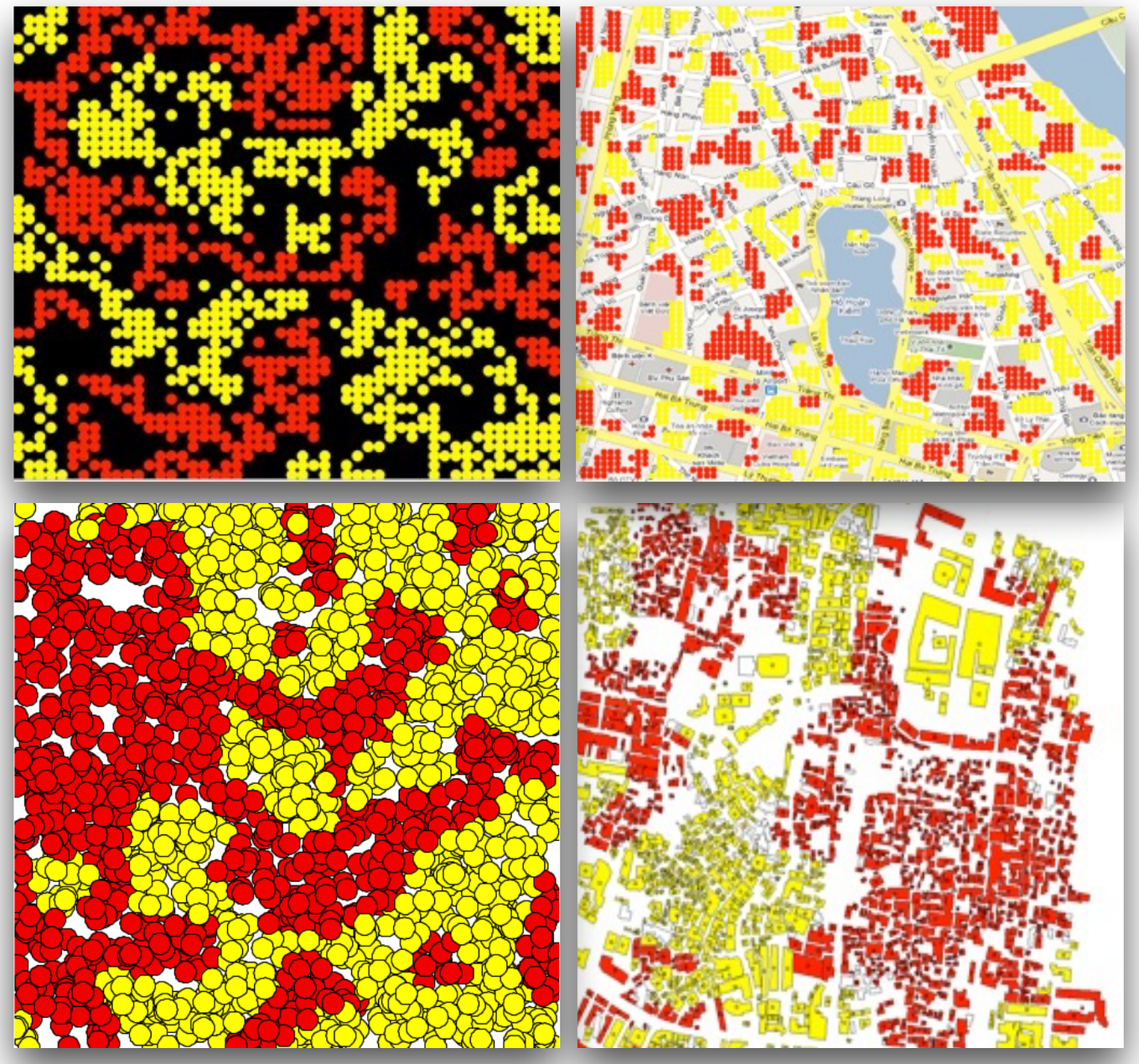
final situation (equilibrium)
Segregation index : 94 %

Models available in GAMA and Netlogo Model libraries.

Spatially explicit segregation

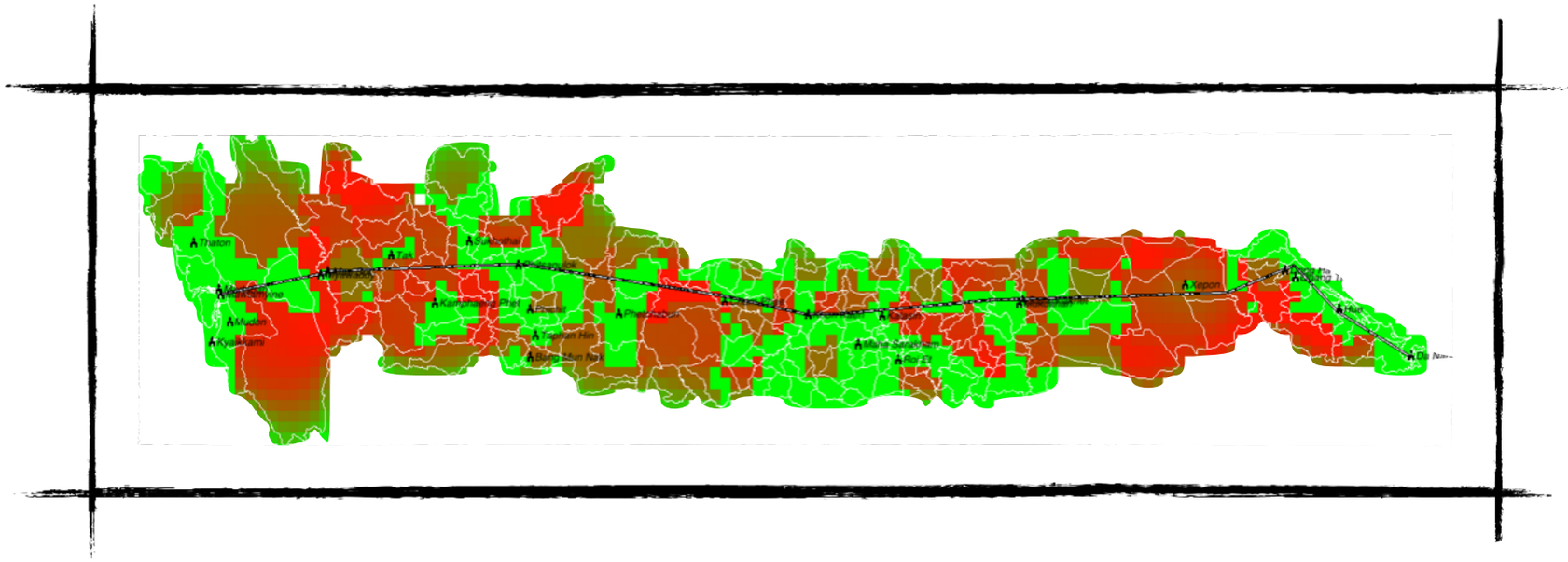
- An interest of agent-based models is that they can be **initially** designed **simple** and becomes **more and more complex**, e.g. by using realistic data.

- The same segregation model can be used on continuous or discrete (grid) environment, on grid built using Google Maps or using GIS data.



Voir aussi : Crooks, A. T. (2010), Constructing and Implementing an Agent-Based Model of Residential Segregation through Vector GIS, *International Journal of Geographical Information Science,* 24(5): 661-675.

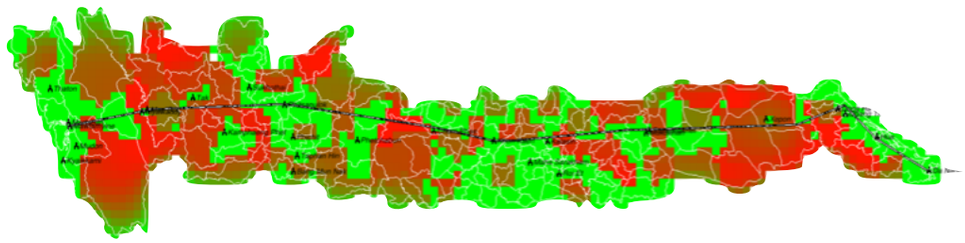
Examples of modelling projects



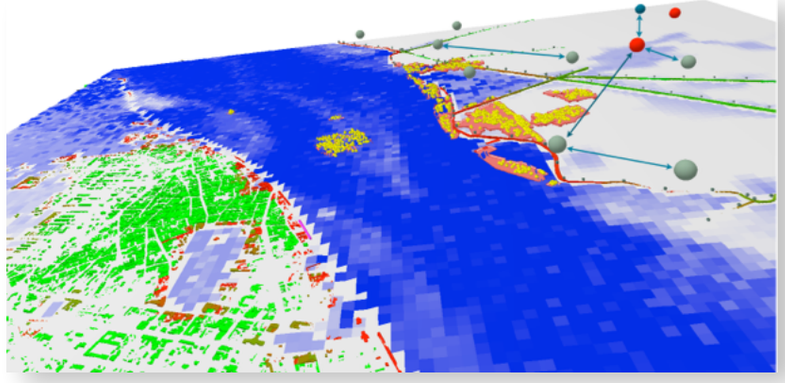
Some examples…

- Understanding and exploring urban spatial dynamics
  - Case study: Can Tho (Vietnam)

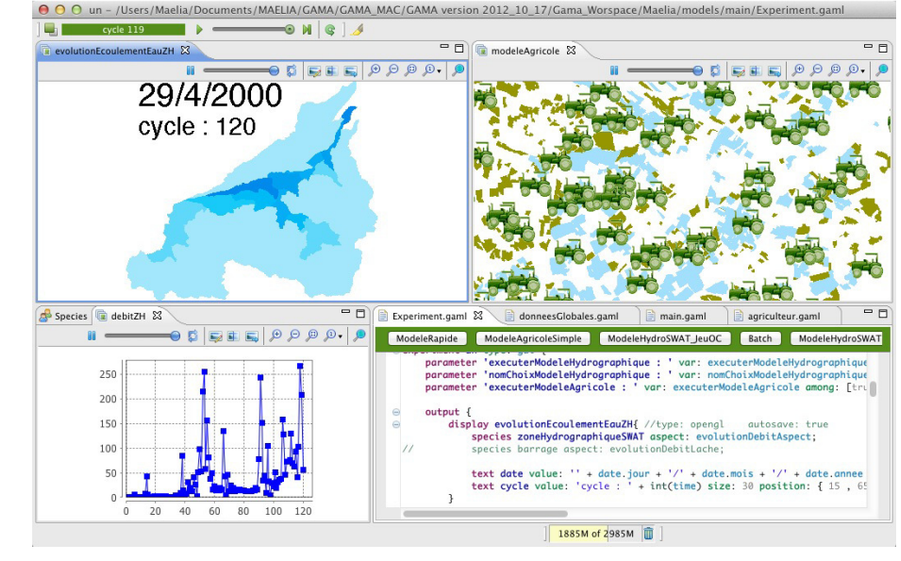
- What incidence do the economic exchanges between ASEAN countries have on the dengue spread?
  - Case study : Vietnam-Myanmar corridor



- Reproducing and exploring past events using agent-based geo-historical models
  - Case study: floods of 1926, Hanoi (Vietnam)



- Assessment of the social, economic and environmental impacts of the various alternative of definition and management of (new) water Volume Available for Agriculture
  - Case study: Adour-Garonne basin (France)



Details about vocabulary

- Agent-based Modeling (ABM)
- Individual-based Modeling (IBM)
- Multi-Agent-Based Simulation (MABS)

Sources

- François Bousquet
- Alexis Drogoul
- Philippe Caillou