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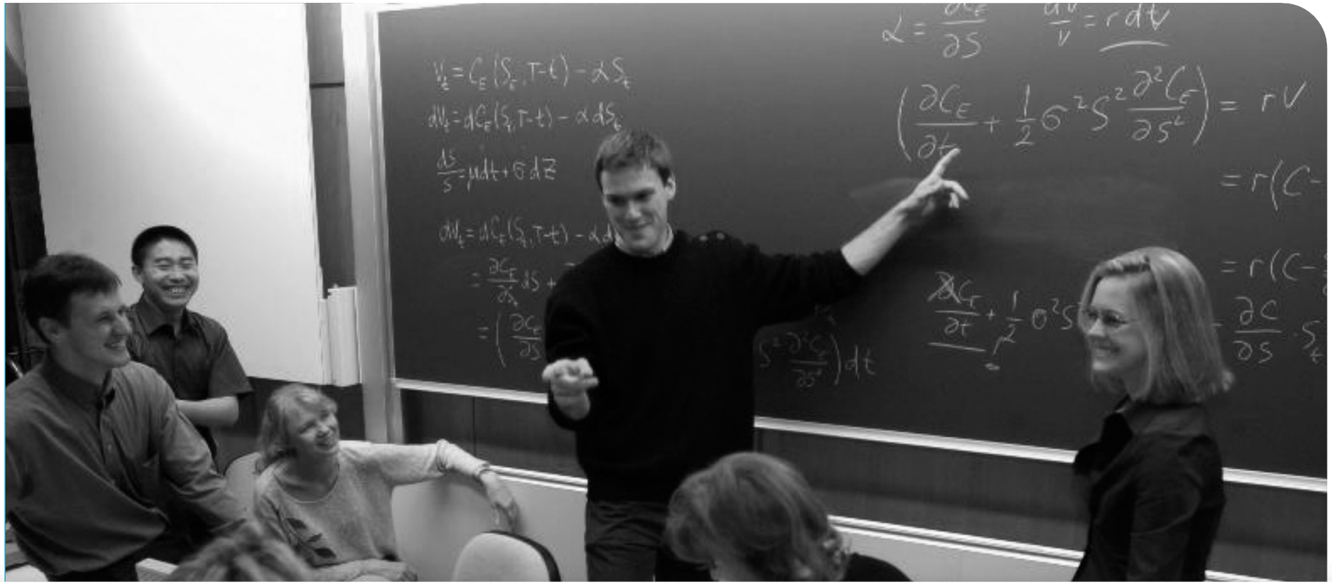


Ecole doctorale en Psychologie sociale

Techniques de simulation appliquées à la résolution de problèmes sociaux

Modèles et outils modernes de la simulation en sciences sociales

Andres Perez-Uribe, HEIG-VD

| le savoir vivant |

Thursday, January 25, 2007

Models

"a miniature representation of something"

Merriam-Webster

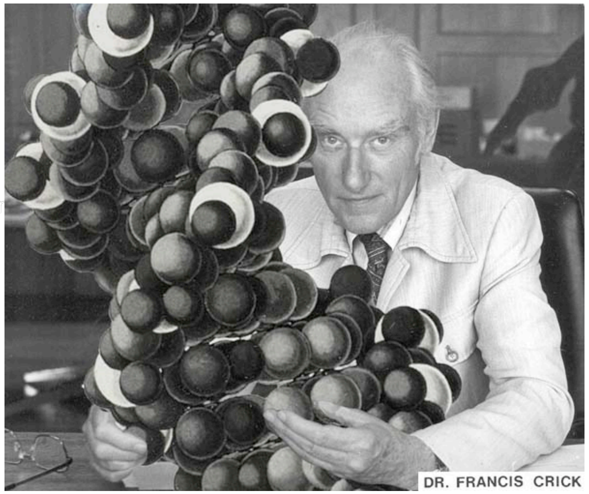
"... [a] representation, or description designed to show the structure or workings of an object, a system, or a concept."

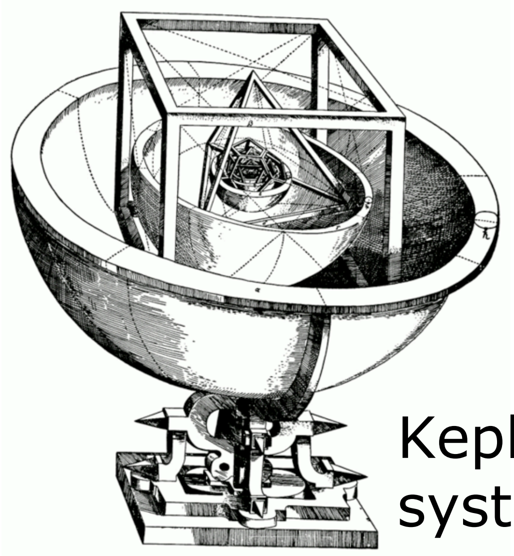
Wikipedia

Learning with models

Models are vehicles for learning about the world. Significant parts of scientific investigation are carried out on models rather than on reality itself because by studying a model we can discover features of and ascertain facts about the system the model stands for.

DNA model





Kepler's solar system model

Learning with models (2)

- Once the model is built, we do not learn about its properties by looking at it; we have to use and manipulate the model in order to elicit its secrets.
- Material models* seem to be unproblematic:

  e.g. we put the model of a plane in the wind tunnel and measure its air resistance
- What about fictional models* ?

* Stanford Encyclopedia of Philosophy

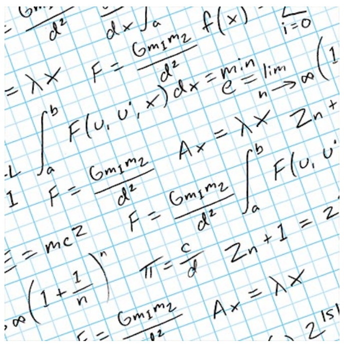
Mathematical models and simulation

- An important class of models is of mathematical nature. In some cases it is possible to derive results or solve equations analytically. But quite often this is not the case.
- The invention of the computer had a great impact as it allows us to solve equations which are otherwise intractable by making a computer simulation.
- Many parts of current research in both the natural and social sciences rely on computer simulations.

What is a simulation?

- The aim of a simulation is to solve the “equations of motion” of a model, which is designed to represent the time-evolution of its target system.
- If the data generated by the equations and the real data "agree" (or are close), then we gain confidence that the set of equations will lead to a good description of the real-world system.

e.g.,migration



equations

simulations

Top-down approach

In the top-down approach to modeling an overview of the system is formulated, without going into detail for any part of it.

Each part of the system is then refined by designing it in more detail.

Each new part may then be refined again, defining it in yet more detail until the entire specification is detailed enough to validate the model (i.e., to match the real data).

More on simulation

- BUT, computer simulations are not only useful for "solving" analytically-intractable equations…
- Computer simulations can be used similar to "thought experiments" (from the German term *Gedankenexperiment)* in philosophy by programming scenarios to help us understand the workings of our object of study.

Bottom-up approach

- In the bottom-up approach to modeling, we start by specifying the individual parts of the system in great detail. The parts are then linked together to form larger components, which are in turn linked until a complete system is formed.
- This strategy often resembles a "seed" model, whereby the beginnings are small, but eventually “grow” in complexity and completeness.

How to use these kind of models?

By rerunning the tape!

"What if the [historical] tape were run again ?”
Stephen Jay Gould

The approach is to rerun the experiments under a wide range of conditions (parameters) in order to statistically analyze the obtained results.

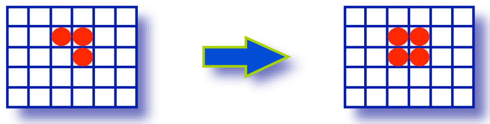
Cellular automata

- The first kind of model we present herein consists of an array of identical cells.
- The communication between cells is limited to local interaction.
- Each individual cell is in a specific state which changes over time depending on the states of its local neighbors.
- The cells change their state synchronously
- Cellular automata were invented by John von Neumann in the 1950s.

The game of life

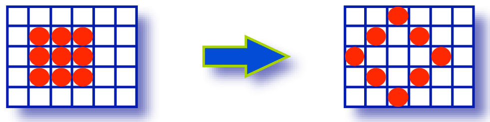
(John Conway)

- Birth of a cell



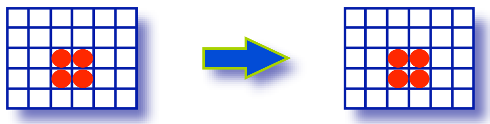
- three neighbors

- Death of a cell



- More than three neighbors
- Less than two neighbors

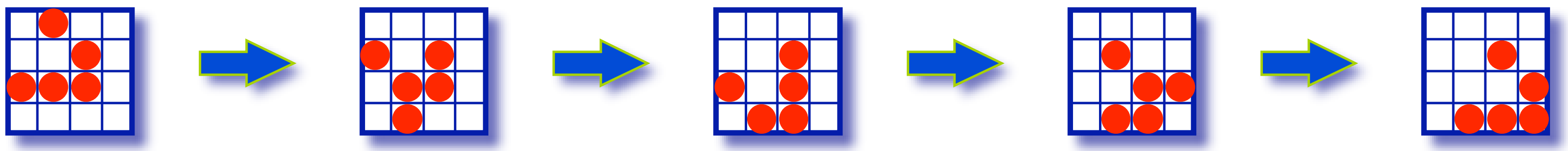
- Survival of a cell



- Two or three neighbors

Given a “pattern” in the cellular automata, one typically observes an unexpected evolution of the pattern.

glider



From cellular automata to agent-based models

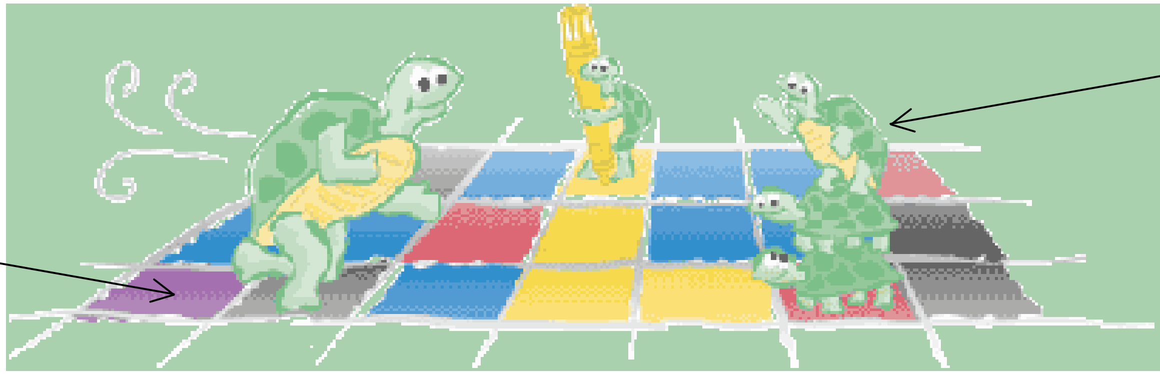
- The cells of a cellular automata can represent physical particles, ants, crowds, etc…
- Researchers have developed cellular automata models to study
  - Segregation
  - Opinion dynamics
  - etc…

- An extension of cellular automata is an agent-based model or individual-based model.

Agent-based models

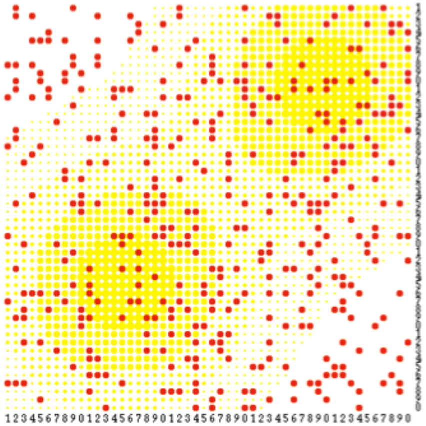
- Agent-based models consist of dynamically interacting rule based agents situated in space and time.
- For instance, agents "live" in a grid-world, they interact with other agents and with the environment (i.e., the grid-world). They can change the state of the environment and the state of other agents.

grid-world

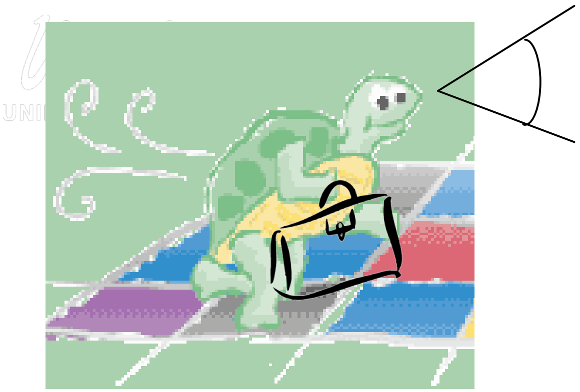


agents

Situated agents



Sugarscape
(Epstein,Axtell, 1997)



-The agents "live" in a grid-world with a particular dynamics.

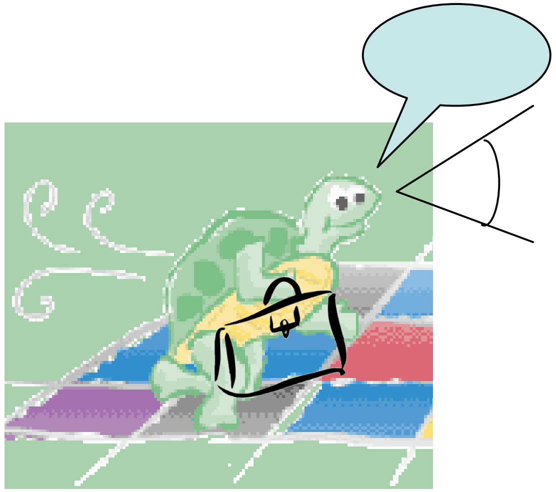
-The agents "live" during a limited number of simulation time steps.

-The agents move but need energy to move (metabolism). If they lack of energy they cannot move or even die.

-The agents can perceive their world but in a limited way.

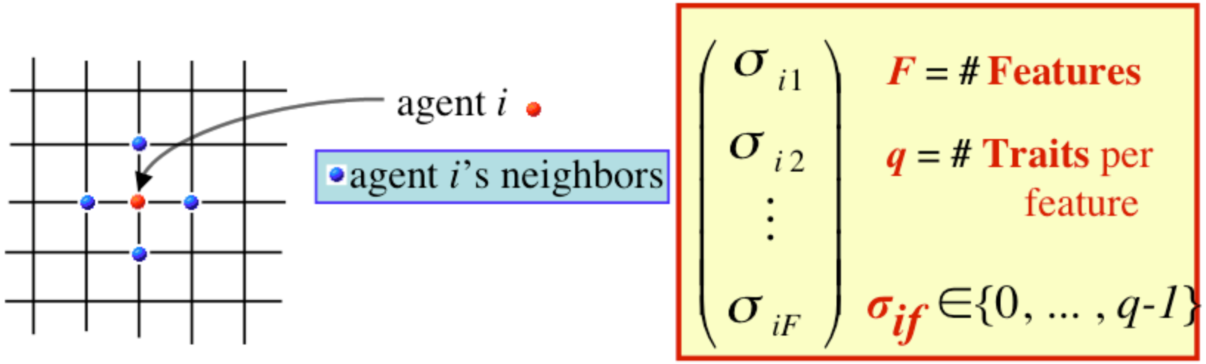
-The agents can stock and share resources according to certain rules.

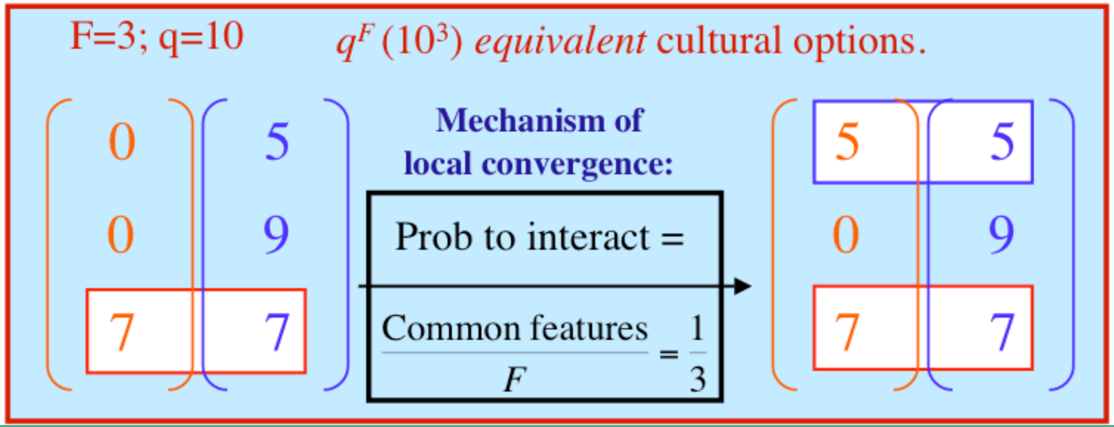
Situated agents (2)



The agents can exchange information

“The dissemination of culture: a model with local convergence and global polarization”, *Journal of Conflict Resolution*, R. Axelrod, 1997



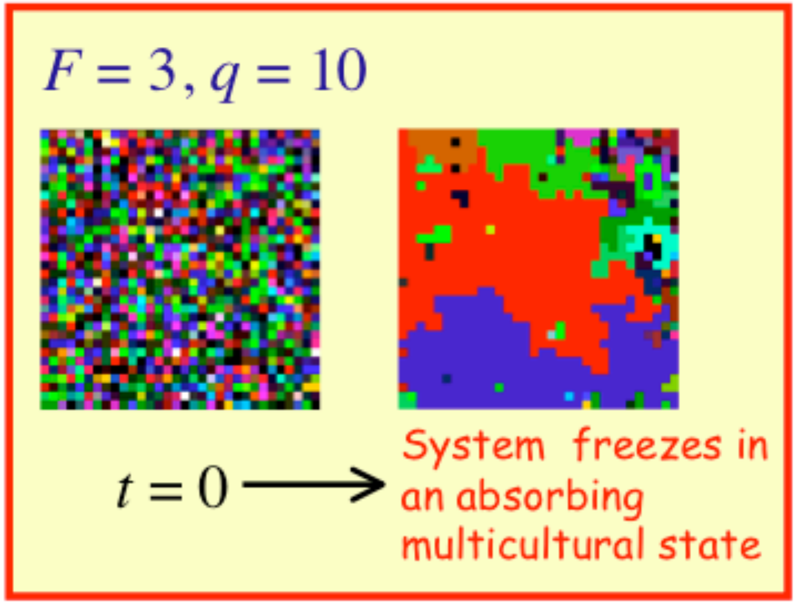


Polarization of ideas

Color code for

F=3, q=2

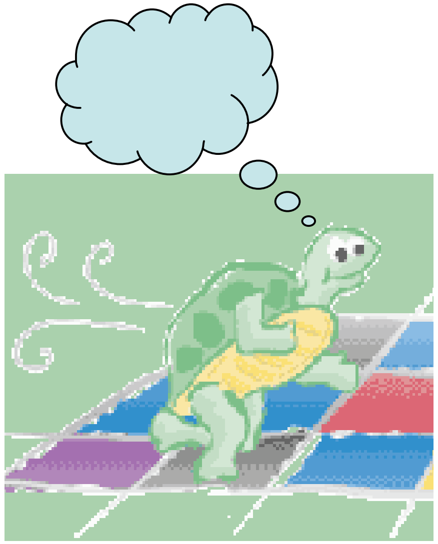
$$\begin{pmatrix}0\\0\\0\end{pmatrix}\begin{pmatrix}0\\0\\1\end{pmatrix}\begin{pmatrix}0\\1\\0\end{pmatrix}\begin{pmatrix}1\\0\\0\end{pmatrix}\begin{pmatrix}1\\1\\0\end{pmatrix}\begin{pmatrix}1\\0\\1\end{pmatrix}\begin{pmatrix}0\\1\\1\end{pmatrix}\begin{pmatrix}1\\1\\1\end{pmatrix}\begin{pmatrix}f=0\rightarrow R\\f=1\rightarrow G\\f=2\rightarrow B\end{pmatrix}$$



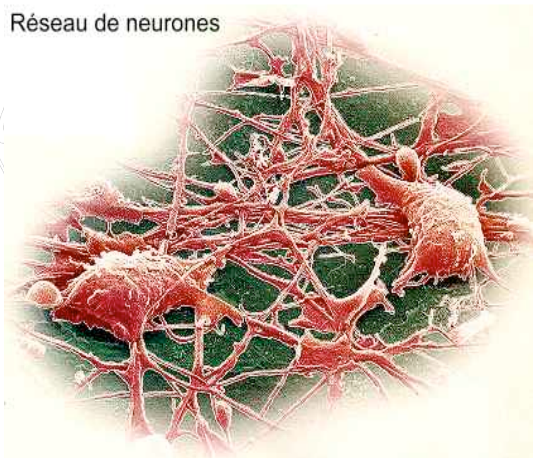
The model illustrates how local convergence can generate global polarization

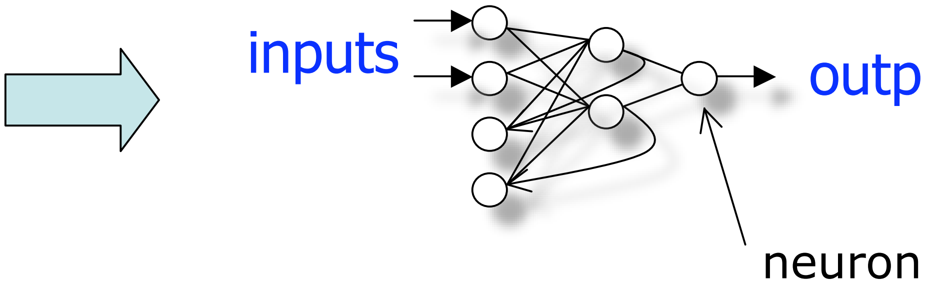
Cultural diversity = number of domains

Learning agents



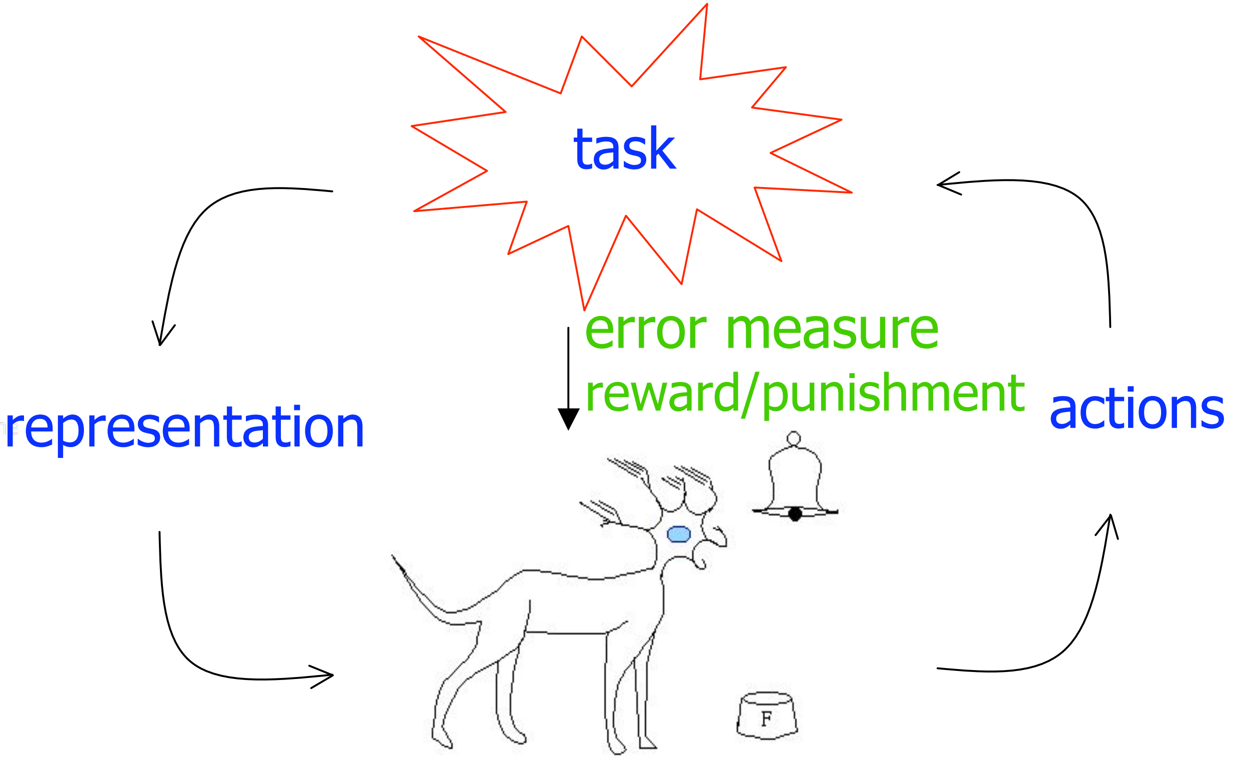
The basic functionality of a biological neuron has been modeled by a computational unit that correlates inputs with so-called “synaptic” values. By interconnecting such artificial neurons we can build artificial neural networks to provide the agents with some “learning” capabilities.





Artificial learning

Artificial learning is achieved by giving examples to the agent or by trial-and-error learning coupled to a reward/punishment mechanism.



El Farol bar problem

(Brian Arthur, 1994)

El Farol bar,
Santafe, CA

N people decide independently each week whether to go to a bar that offers entertainment on a certain night. Space is limited, and the evening is enjoyable if things are not too crowded (e.g., if fewer than 60% of the possible N are present).

A person or agent attends the bar *if* she/he expects fewer than 60 to show up, or *stays home* if he expects more than 60 to go.

El Farol bar problem (2)

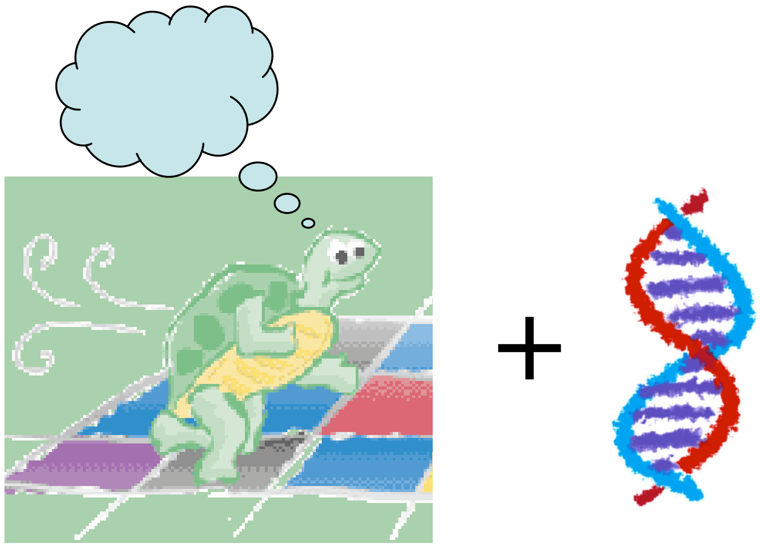
Bounded rationality: unfortunately, it is necessary for everyone to decide *at the same time* whether they will go to the bar or not. They cannot wait and see how many others go before deciding to go themselves.

If all believe *few* will go, *all* will go. Similarly, if all believe *most* will go, *nobody* will go.

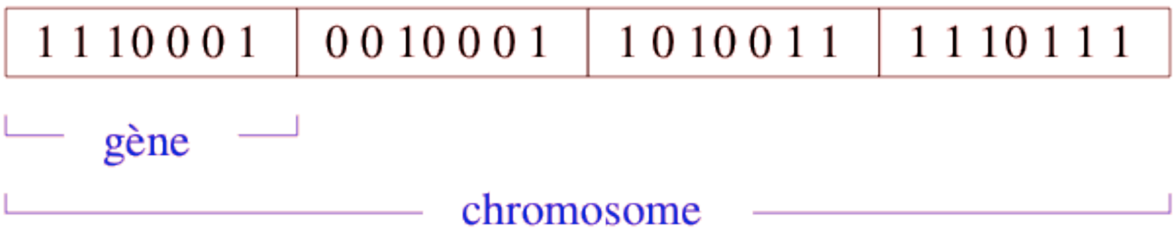
Learning agents attending El Farol

- Arthur proposes the reader to check if it can be useful for the agents to use certain predictors of the number of people attending the bar:
  - same as last week's
  - a (rounded) average of the last four weeks
  - the same as 2 weeks ago (2-period cycle detector)
- Researchers have tested what happens if the agents learn by trial-and-error coupled to a reward given by the satisfaction of attending the bar.
- "The level at which humans can apply perfect rationality is surprisingly modest." "I believe that as humans in these contexts we use *inductive* reasoning",[i.e.,] "we use simple models to fill the gaps in our understanding" B. Arthur

Evolving populations of agents

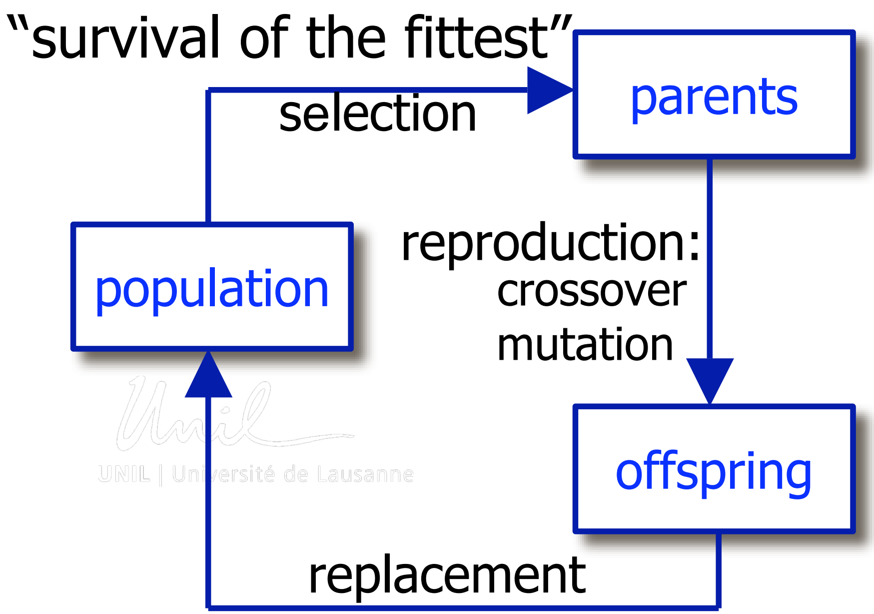


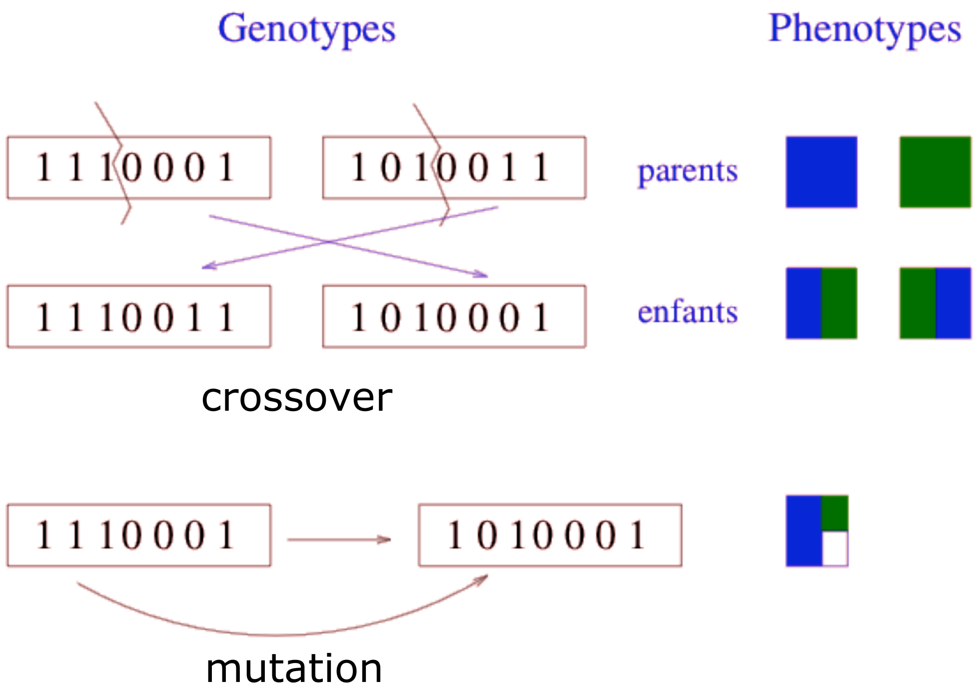
The agents of a model can be endowed with bit-strings that code for certain traits of the agents or their behavior.



Artificial evolution

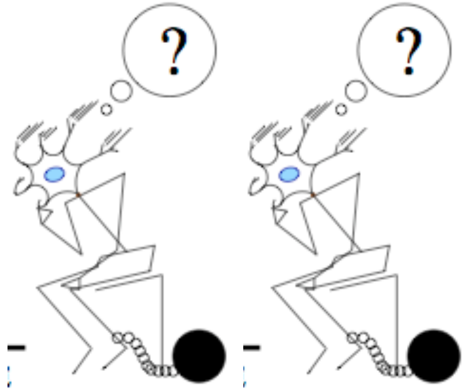
(John Holland, 1970s)





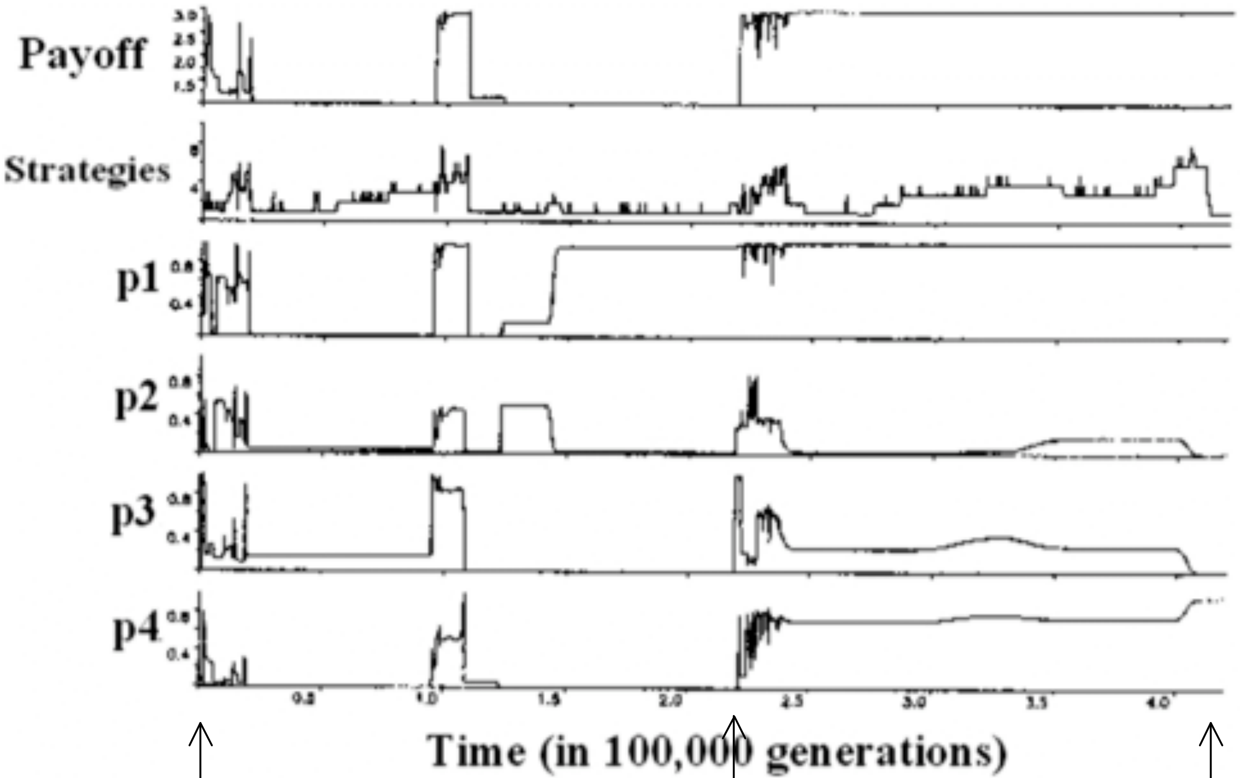
Evolving tit-for-tat

(Nowak & Sigmund, 1993)



- Iterated Prisoner Dilemma
- Strategies takes not only opponent into consideration, but itself as well
- A strategy can be represented as a 4–dimensional vector (p1, p2, p3, p4) giving the probability of cooperating after the result of the previous interaction:
  - Reward–payoff (both cooperated)
  - Sucker–payoff (if one defectes, the cooperator receives S)
  - Temptation–payoff (if one defects, the defector receives T)
  - Punishment–payoff (both defected)
- Example: TFT = (1 0 1 0)

Evolving tit-for-tat and beyond



(0.5, 0.5, 0.5, 0.5)

TFT-like

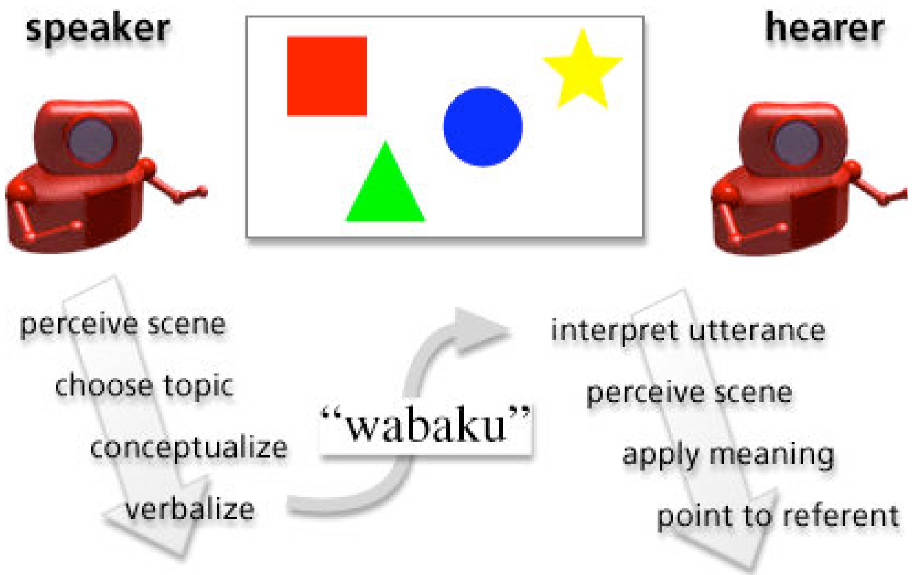
Pavlov-like
(0.999,0.001,0.007, 0.946)

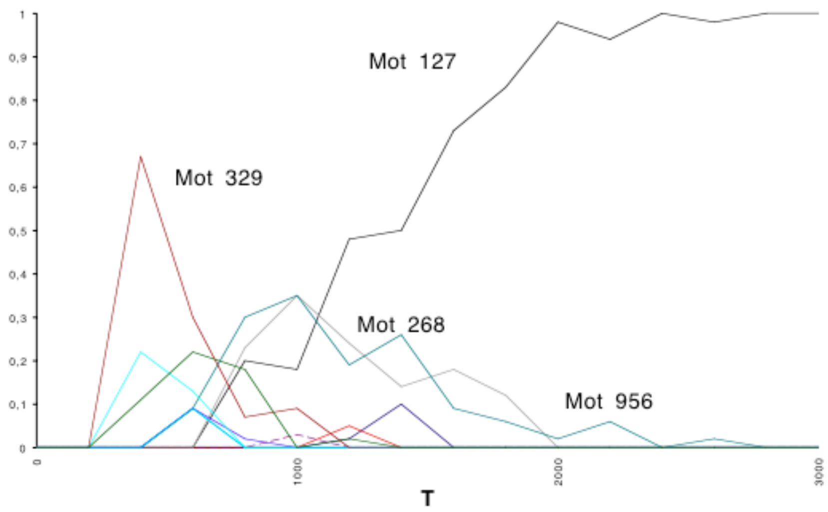
Pavlov strategy
(0.999, 0.001, 0.001, 0.995)

Cooperate after mutual cooperation & defection

Embodied agents

Let's give a body to our agents, real sensors and let them interact with the real world!
"Talking heads experiment" - evolution of a lexicon
Luc Steels, 1999-2000



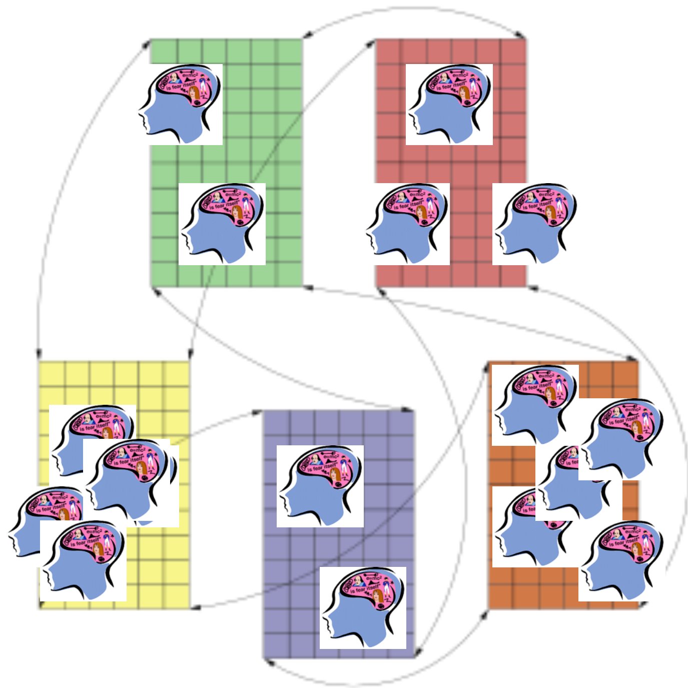


PERPLEXUS

« A Connectionist, Embodied and Situated Agent-Based Approach for Studying the Dissemination of Culture »

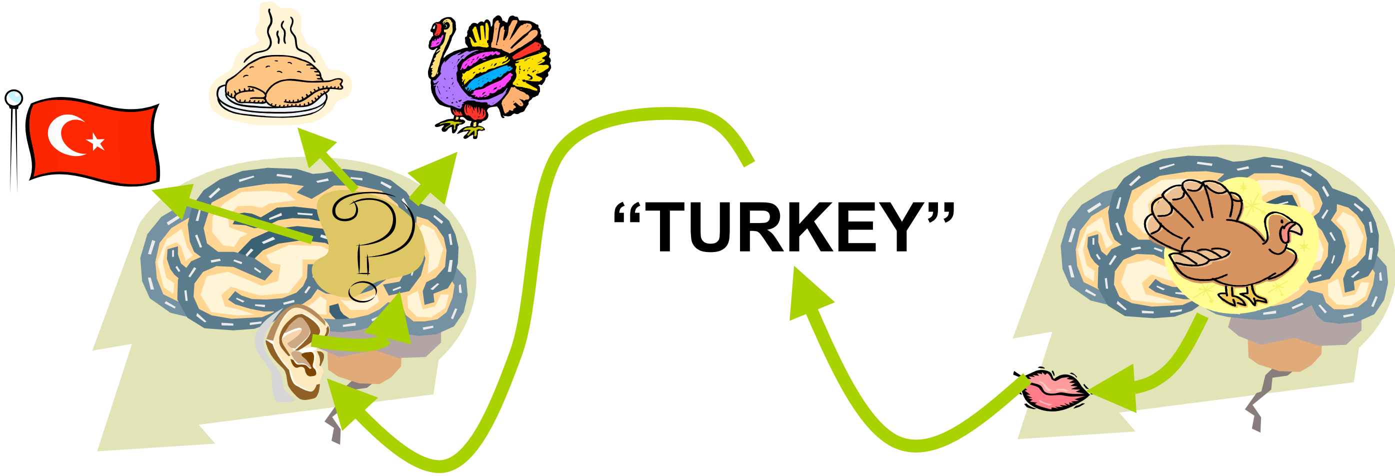
J. Peña, O. Jorand, H. Volken, and A. Perez-Uribe

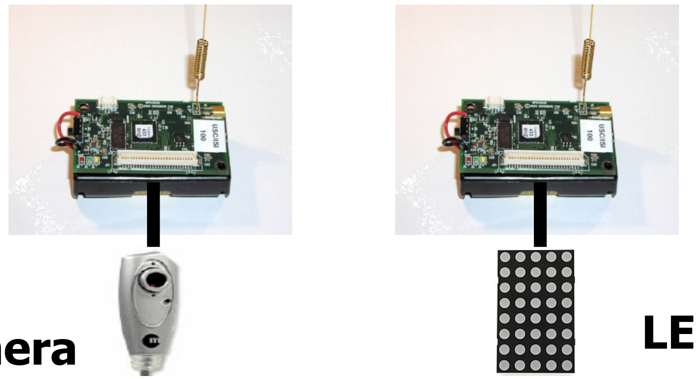
Instead of having agents equally open to any kind of cultural content, we propose to consider agents endowed with biases "materialized" by means of artificial neural networks.



PERPLEXUS (2)

"Materialization" of ideas in the world....

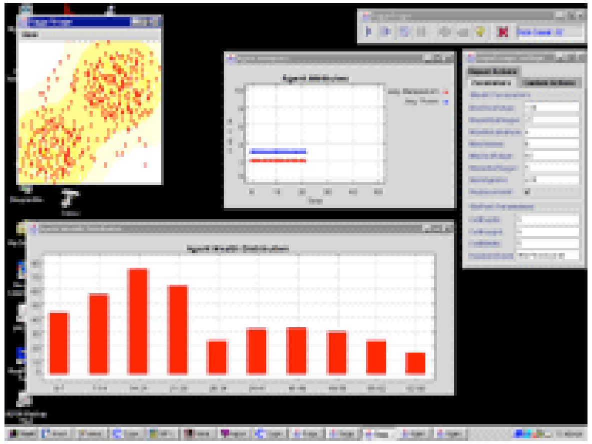




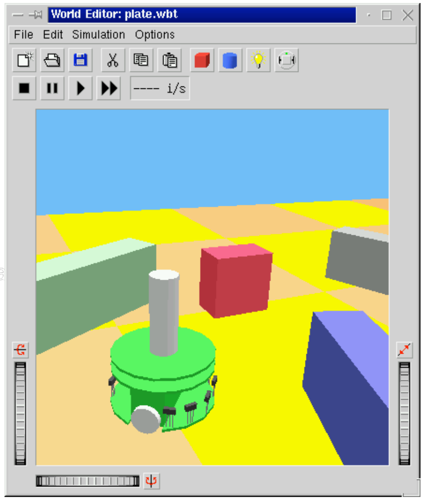
Digital Camera

LED Matrix Display

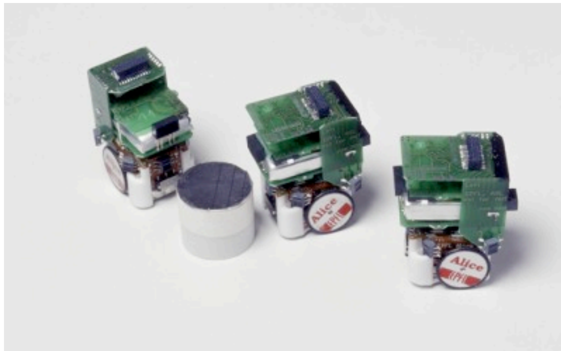
Tools



- Netlogo (Netlogo)
- REPAST (Java)
- SWARM (C++)
- MATLAB



Webots robot simulator



Real robot setup

THE END

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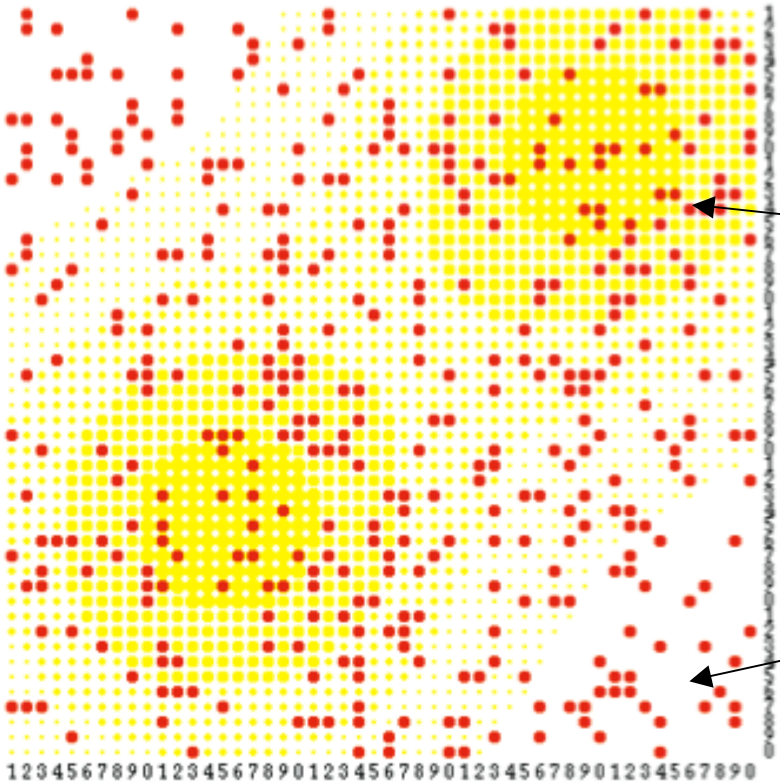
Agent-based models (2)

Example: Sugarscape model (Epstein, Axtell, 1997)



Sugarscape = spatial distribution of « sugar »

Agents (red dots) move, perceive sugar near them, eat sugar to survive, and stock collected-but-not-eaten sugar

At every point (x,y) there is an amount of sugar. The sugar can be consumed by the agents and it can also growback to a certain level.