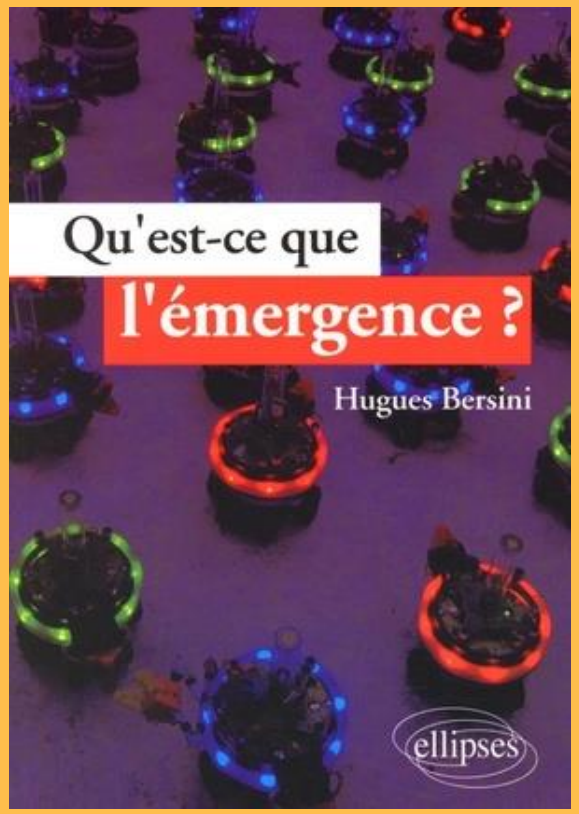
Agent-Based Modelling

Hugues Bersini
IRIDIA/ULB

Introduction: Weak emergence



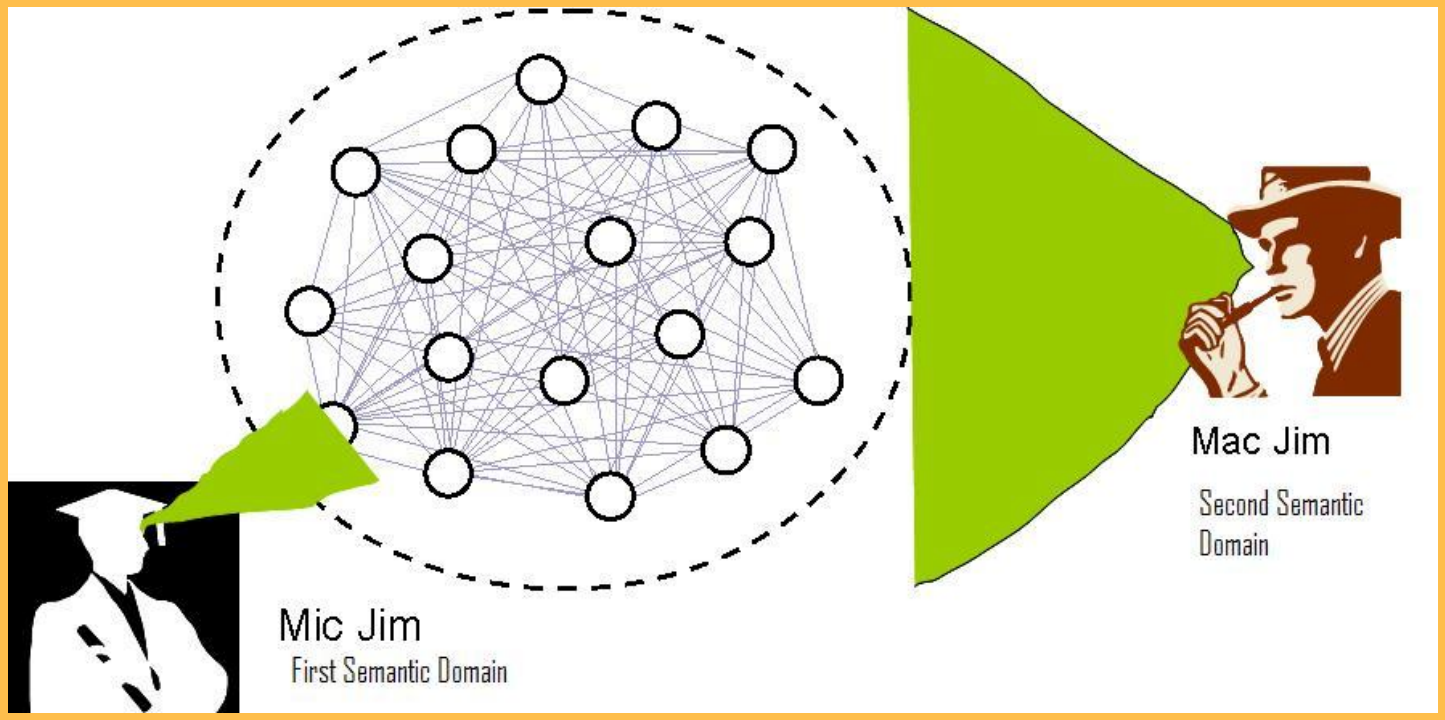
« La cellule vivante ne contient rien que
des particules minérales […]
et pourtant il est, de toute évidence,
impossible que les phénomènes caractéristiques
de la vie résident dans des atomes d'hydrogène,
d'oxygène, de carbone et d'azote.
La vie est dans le tout, non dans les parties… ».

Durkheim dans les
« Règles de la méthode sociologique »

Mac and Mic Jim

The whole is more than…

1 + 1 = 3

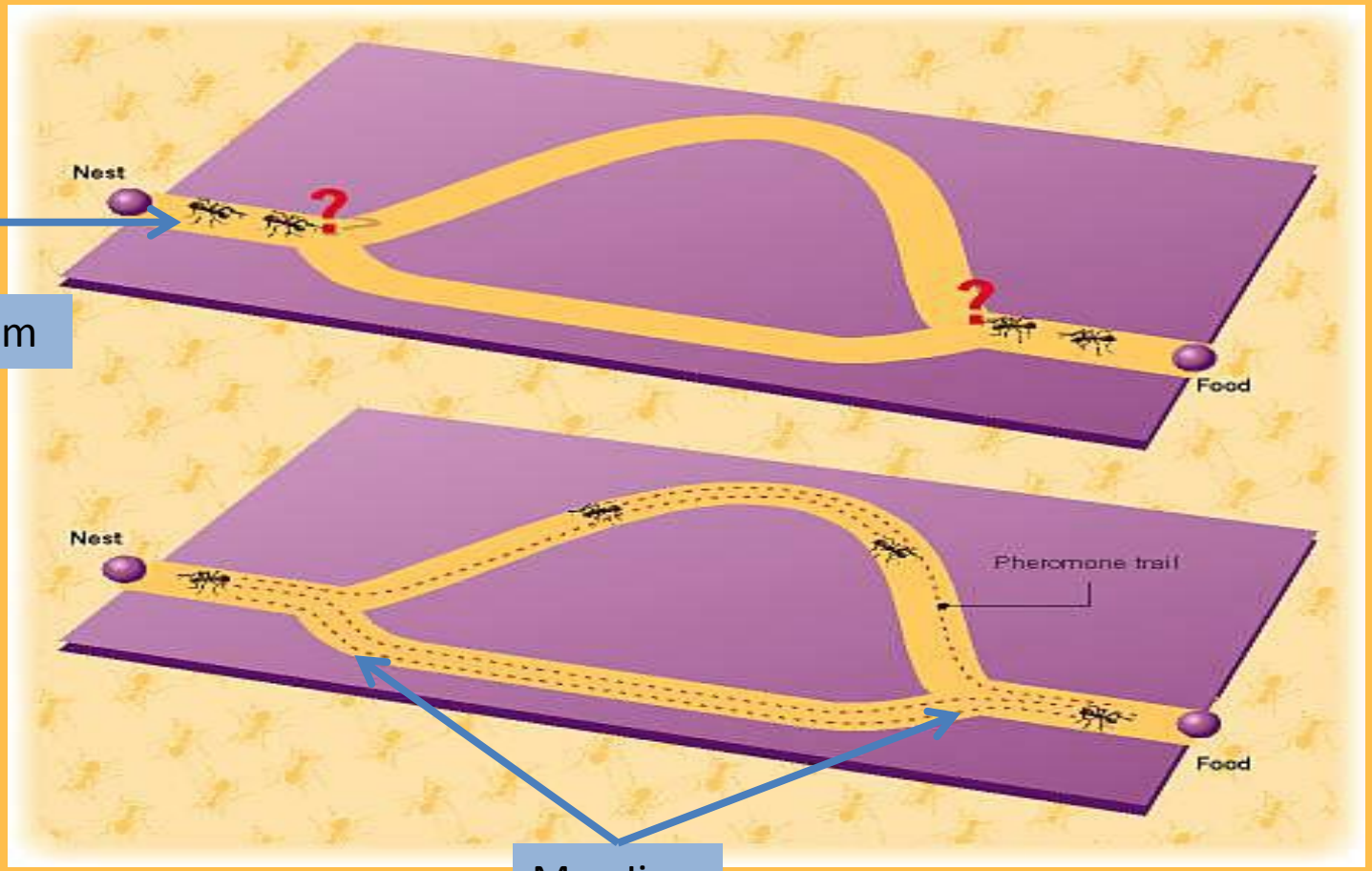


Three emergent phenomena:
1) A traffic jam

Mac Jim

Mic Jim

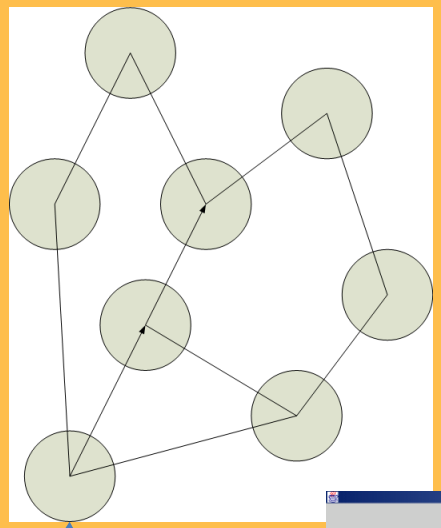
2) The ants shortest path

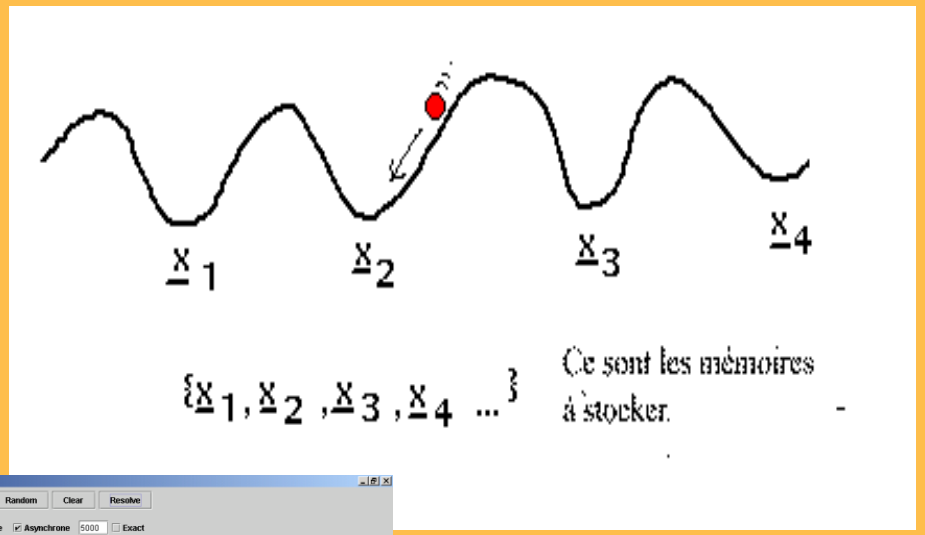


Mic Jim

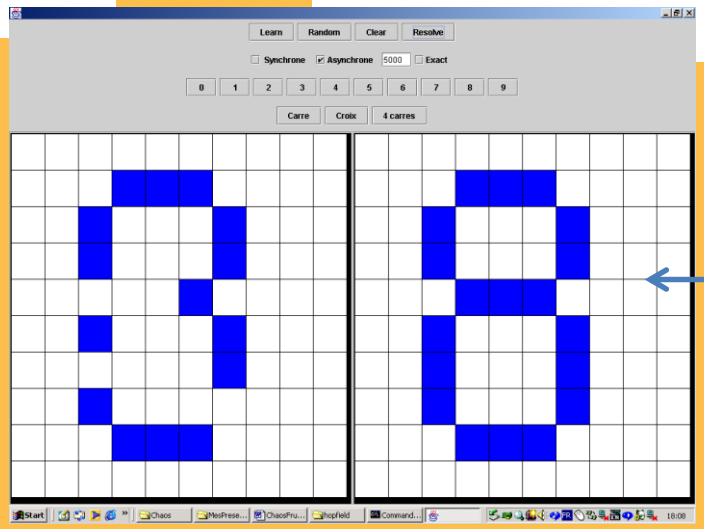
Mac Jim

3) Associative memories in neural networks





Mic Jim



Mac Jim

Before all: Science has to stay reductionnist.

We need to modestly stay reductionist:

→ no vitalism, no creationism

→ no mind/body problem

→ no top-down « supervenience »

Still interesting questions:

The phenomenon emerges but « FOR WHO??? »

Again and again the « observer » problem

Who is Mac Jim with respect to Mic Jim ?

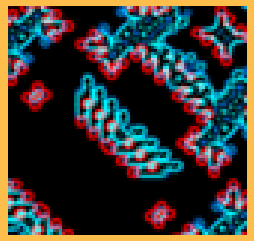
Can Mic Jim perfectly predict what is seen by Mac Jim ?

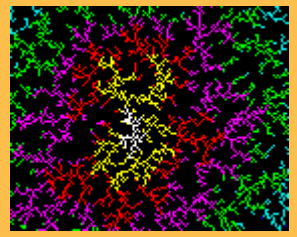
→ Yes is the answer of reductionism.

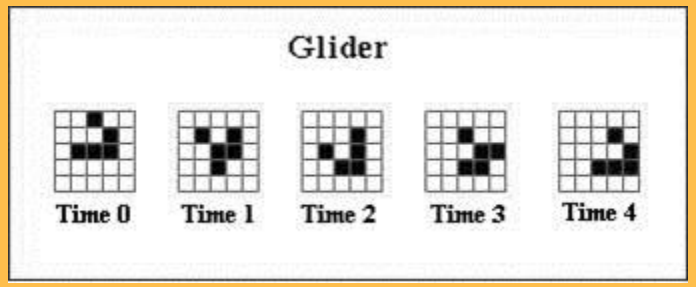
Who says the truth ?

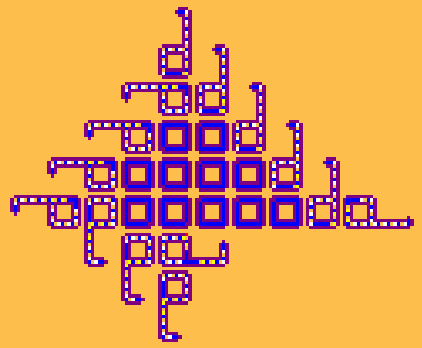
But then, what's the legitimacy of Mac Jim ?

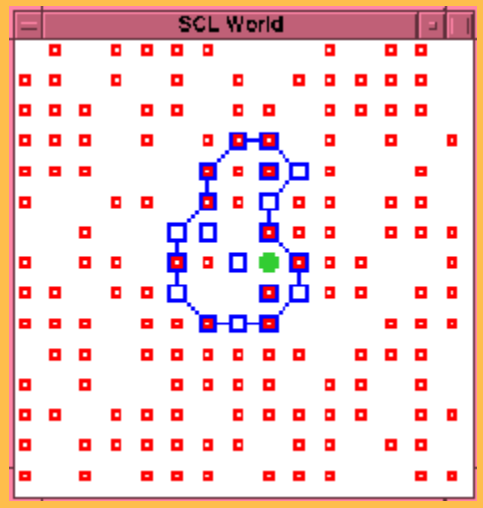
Cellular automata: the perfect illustration of weak emergence

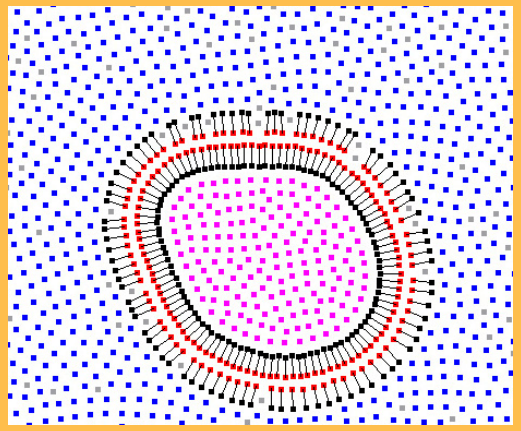




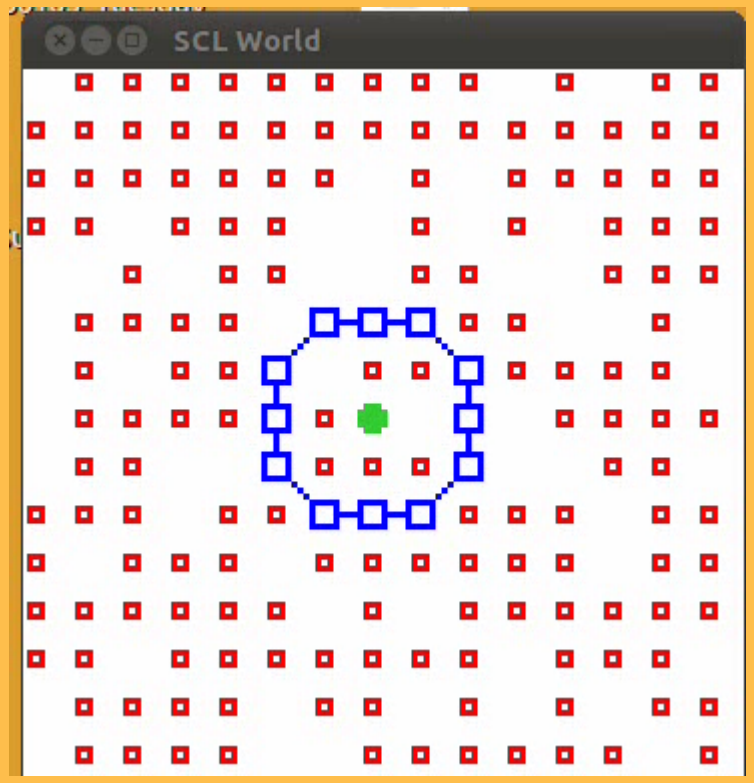


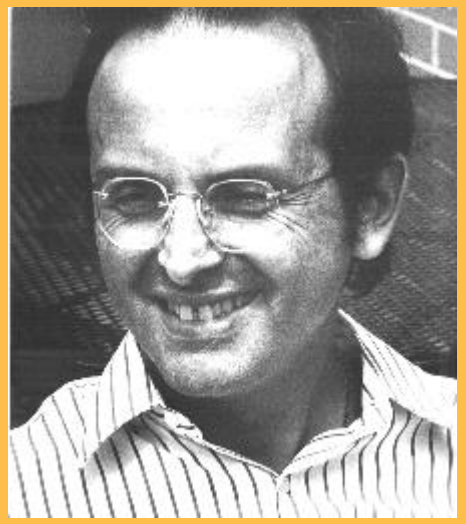




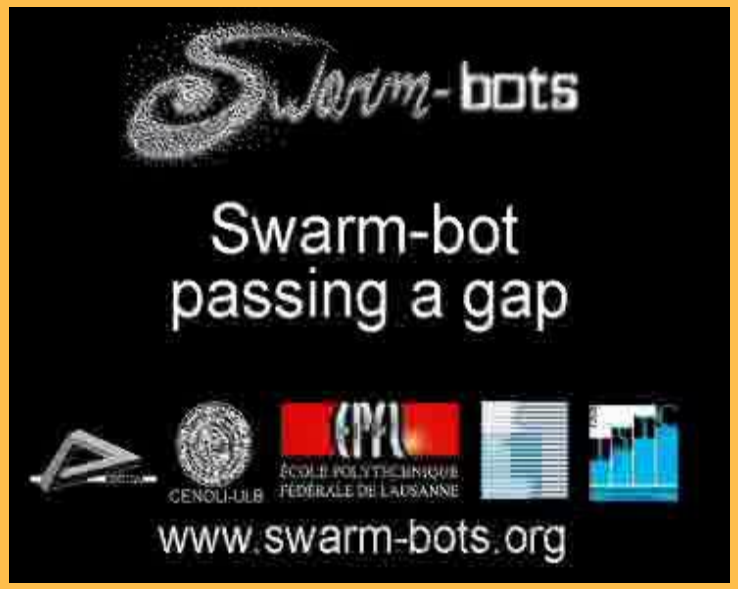


Varela Autopoiesis





Swarm robotics: weak ? strong ?



The big debate on emergence

=

So classical in epistemology on the status of the scientific observer

Need for observer emancipation

Weak Emergence
= epistemic
= gap impossible to analytically fill
= in the eyes of the human observer
= this new semantic domain simplifies analysis, understanding, communication
→ But everything happens « downstairs » !!!!

Strong Emergence
= ontological
= really there

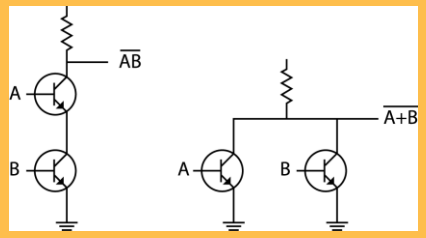
But let's stay reductionist !

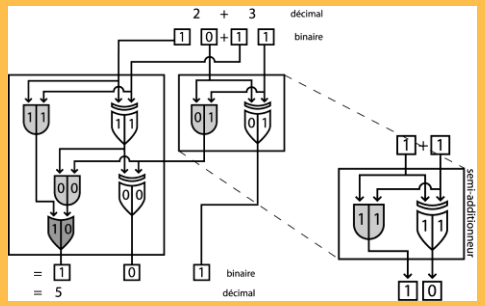
Engineering might help

Engineering = Strong but not spontaneous bottom-up emergence

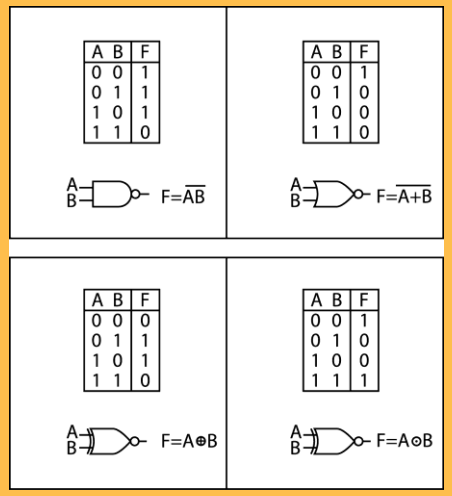
- A car is more than the sum of its parts
- A computer too

molécules





cellules



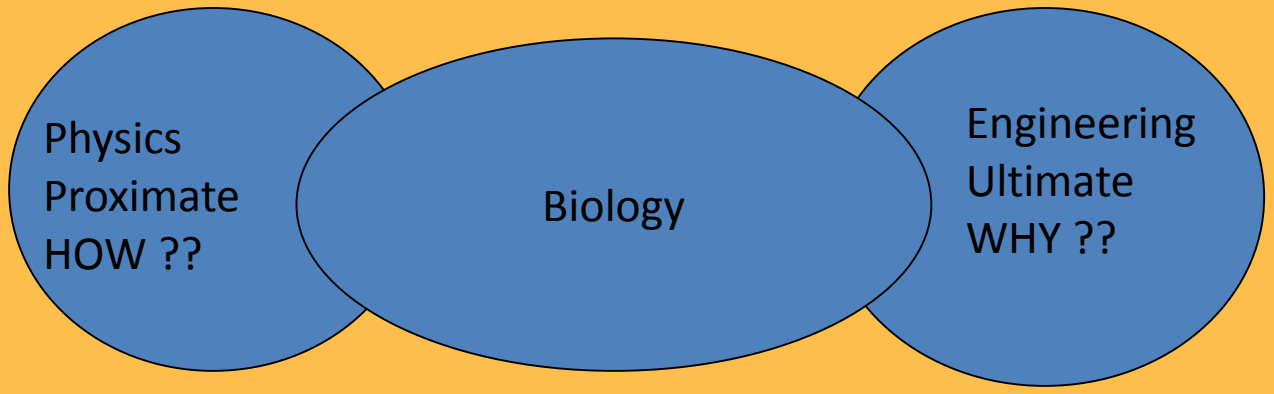
gènes

Mais en biologie,
l'ingénieur doit être aveugle !!!

- Engineering is top-down !!!
- But the "more" is the function for the external user who gains in fitness

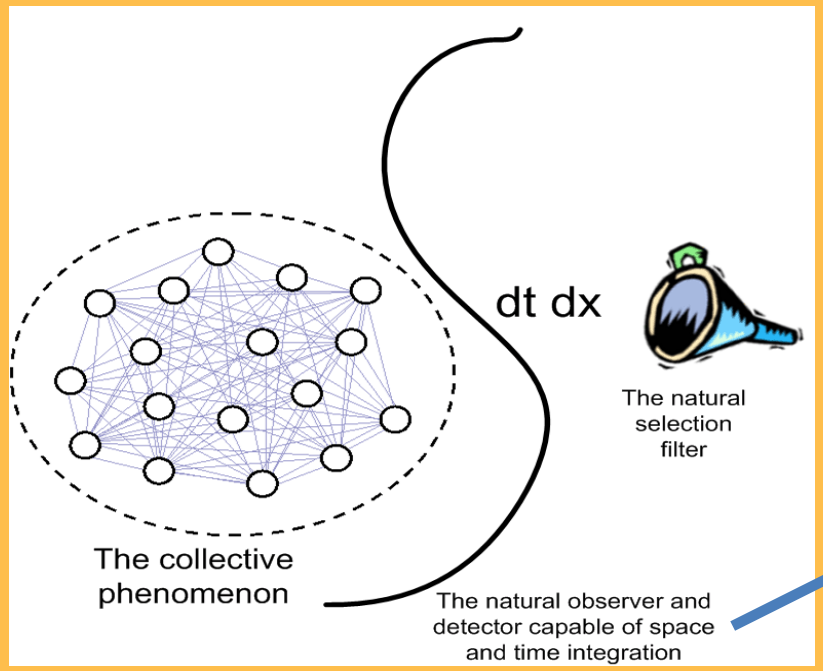
Between engineering and physics … The blind watchmaker of biology

- Physics describes collective phenomenon: the proximate cause
- The engineer describes the function: the ultimate cause



Emergent phenomena are strong for natural selection

The three needed ingredients that biology provides for a collective system to be strongly emergent

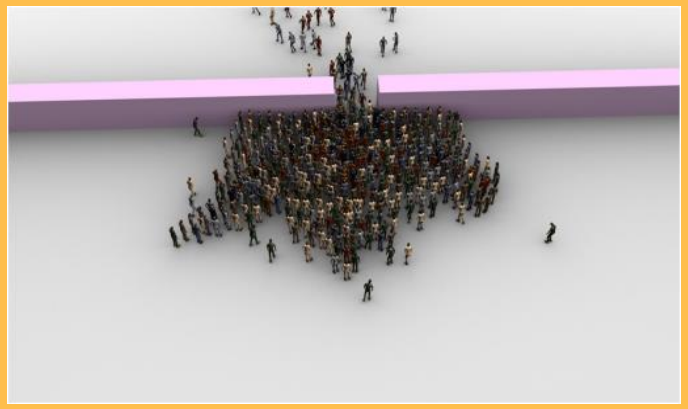


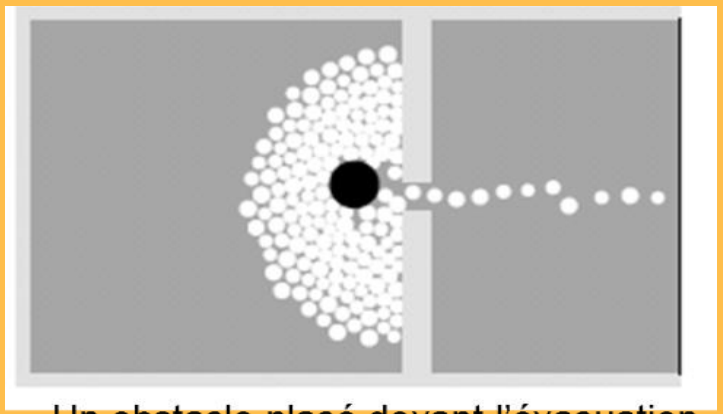
The gap

Fig. 2: The three needed ingredients for a collective phenomenon to be qualified as emergent.

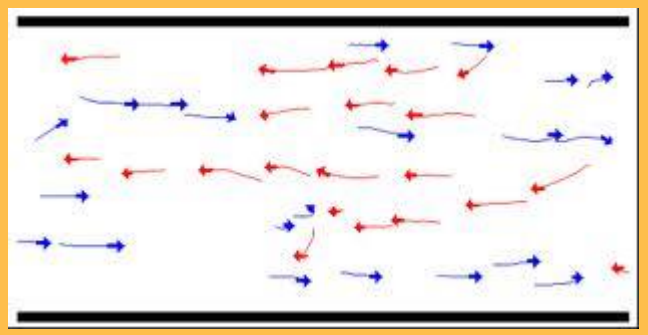
- Sociology = weak emergence
- Surprise of the whole with respect to the parts
- In contrast to statistics that brings back the macro to the micro
- Need to resort to computer simulations
- Let’s consider two very celebrated examples

1) Dirk Helbing – Sociologue à Zurich
Foules sentimentales !



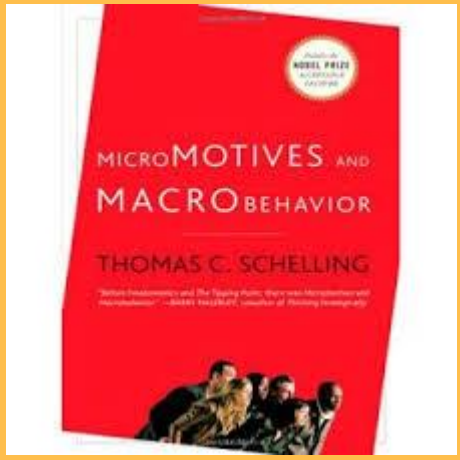


Un obstacle placé devant l'évacuation facilite paradoxalement l'écoulement en cas de panique

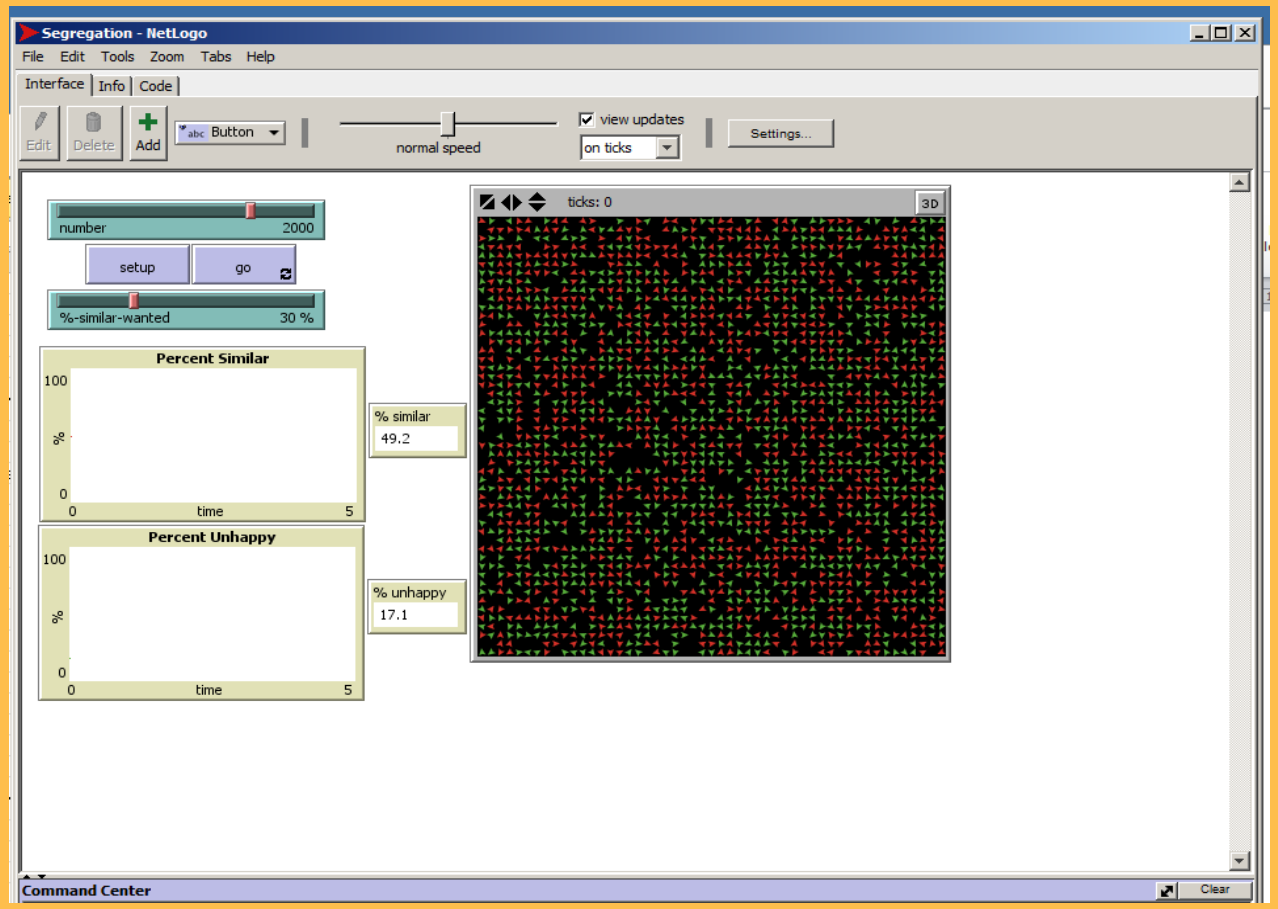


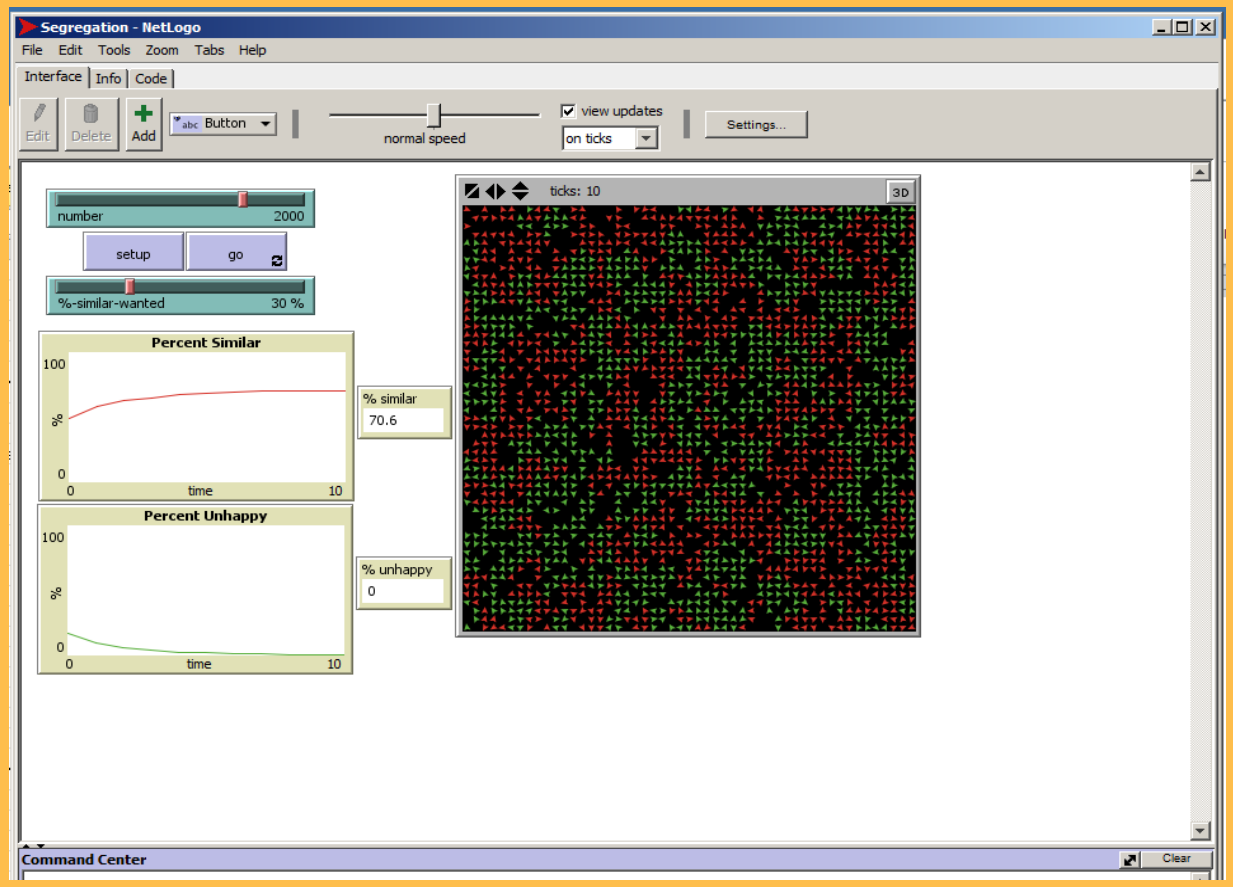
2) Thomas Schelling and segregation

- Thomas Schelling experiment
- How weak racism creates strong segregation

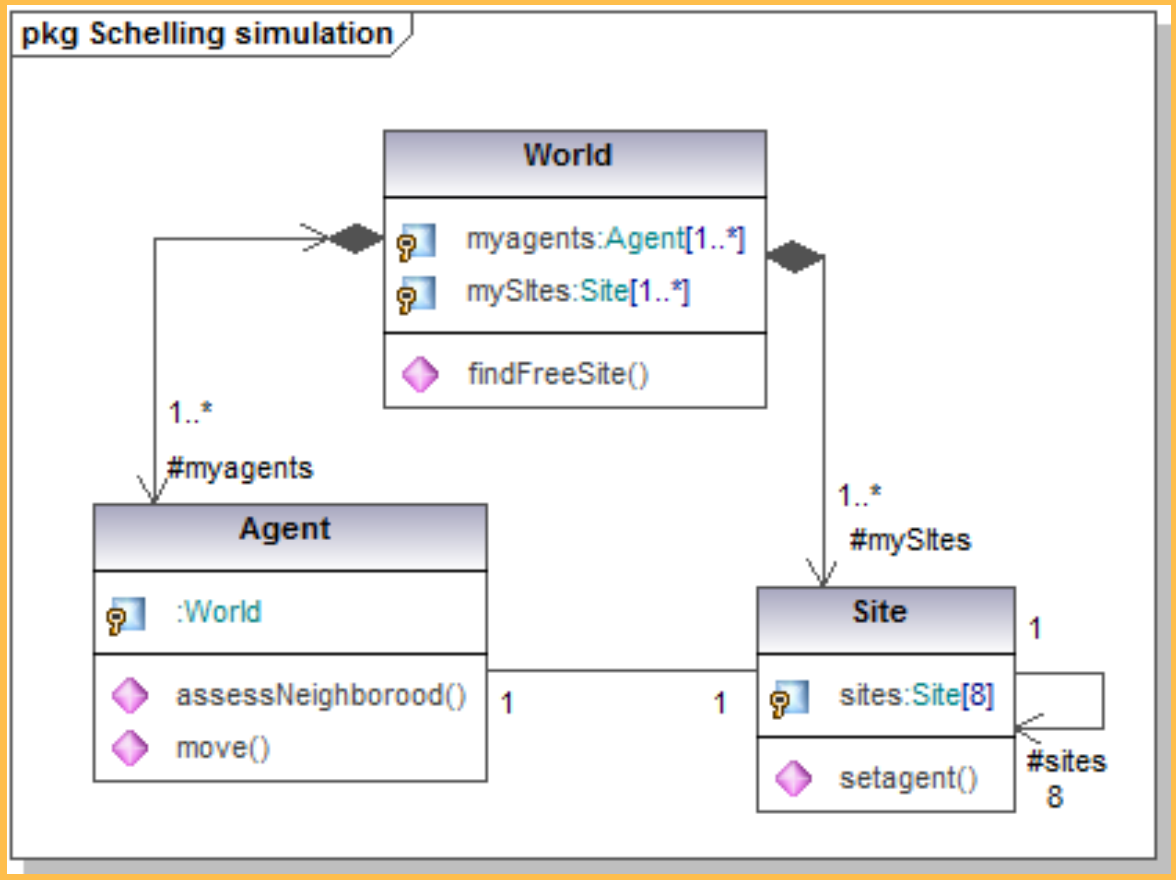


Thomas Schelling and segregation

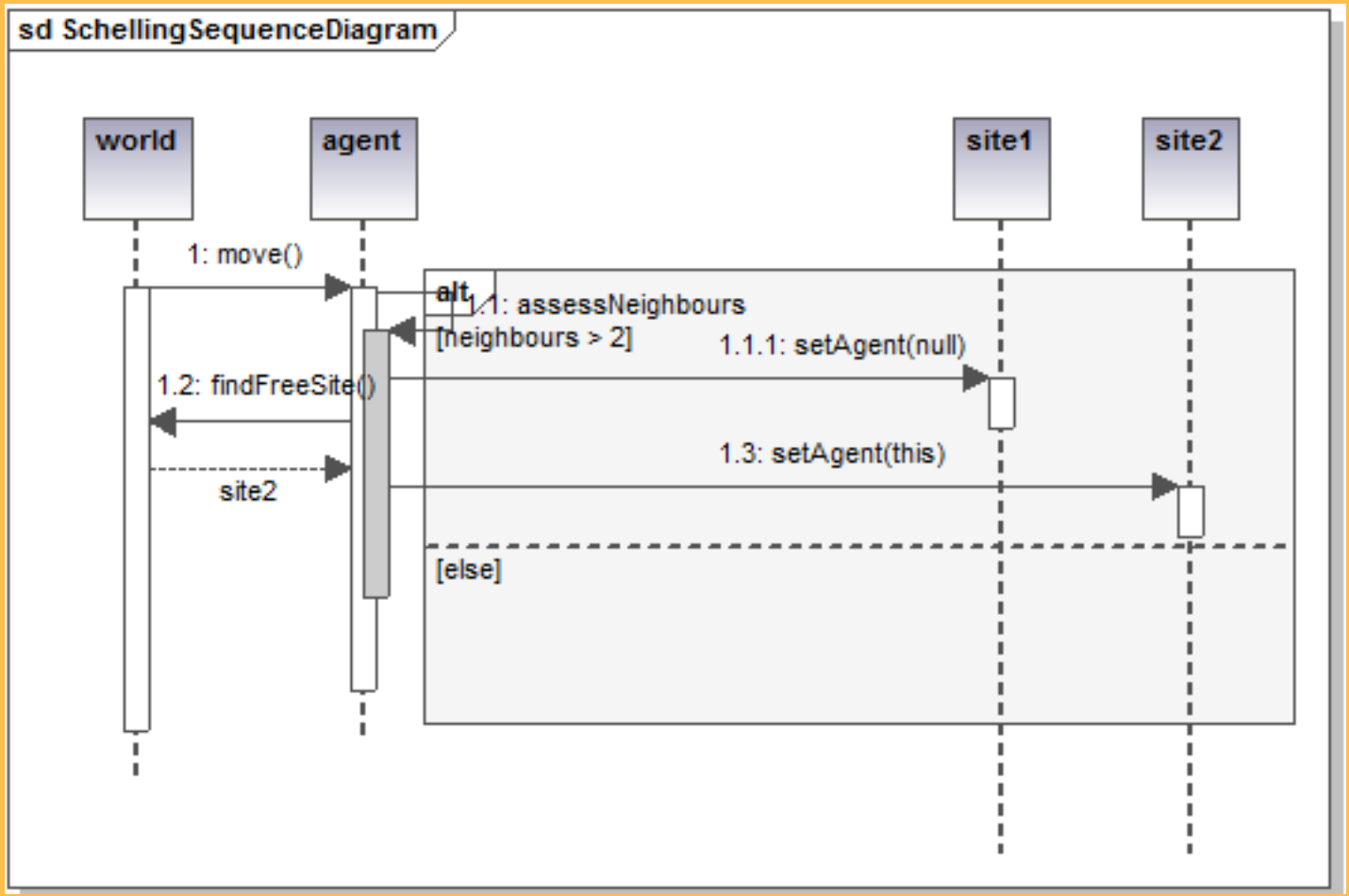



Segregation - NetLogo
File Edit Tools Zoom Tabs Help
Interface Info Code
Edit Delete Add
Button
normal speed
view updates
on ticks
Settings...
number 2000
setup
go
%-similar-wanted 30 %
Percent Similar
100
%
0
0 time 10
% similar
70.6
Percent Unhappy
100
%
0
0 time 10
% unhappy
0
ticks: 10
3D
Command Center
Clear

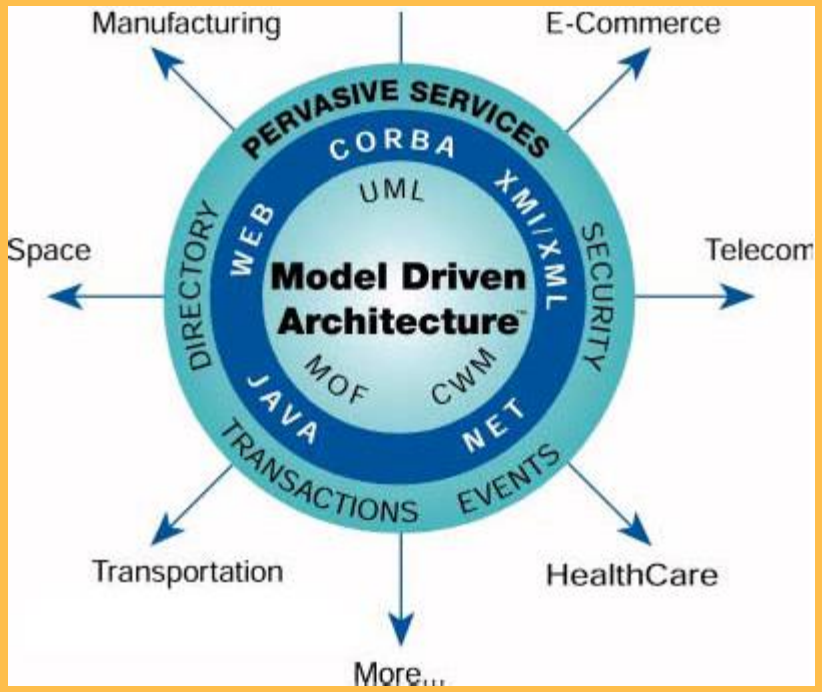
Class diagram



Sequence Diagram



UML -> MDA



→ Third generation programming language

- UML could be the language adopted by natural scientists to express their knowledge
- Could help to homogenize and cross-fertilize existing models.
- We need to stop with “write once run only once !!!”
- Could improve their own understanding of their own field.
- Could disambiguate some of their knowledge
- Just three diagrams need to be understood

Three types of agents of increasing complexity

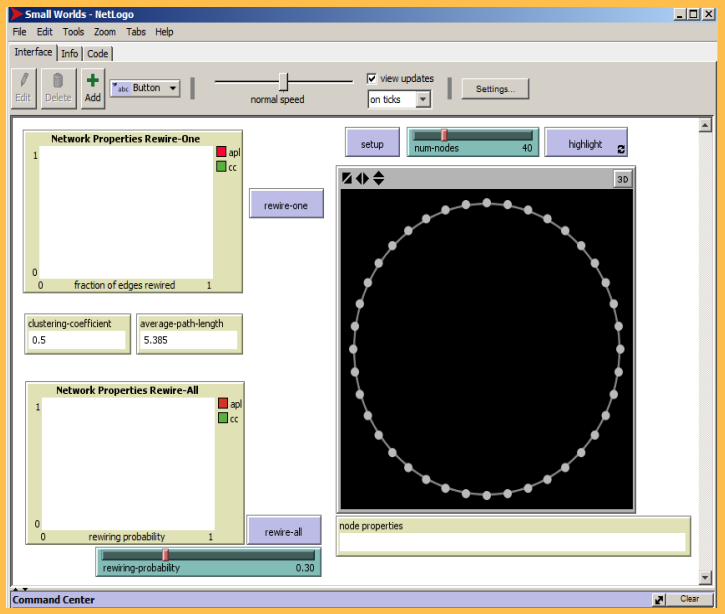
- Automata
  - Such as the birds flocking
- Interested
  - Economy, game theory
- Adaptative
  - They learn, they adapt

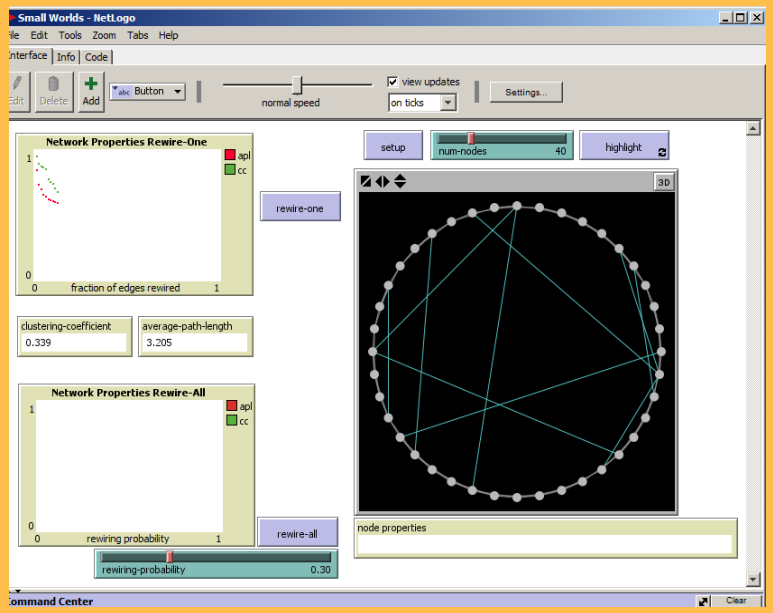
Four more examples

- The small world
- Emergence of cooperation
- Market Self-Regulation
- The dilemma equality/efficiency

1) The small world

Le petit monde: Duncan Watts





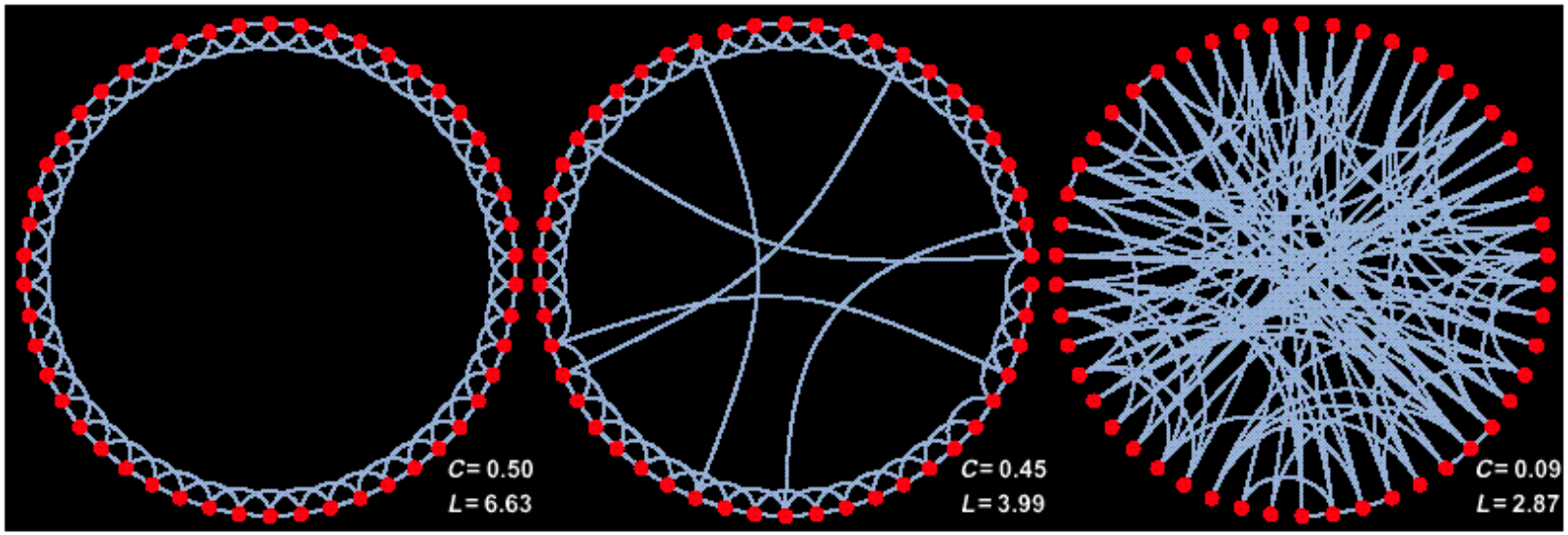
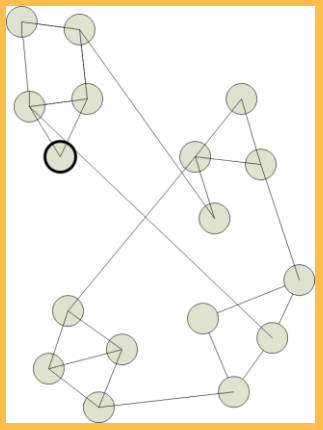
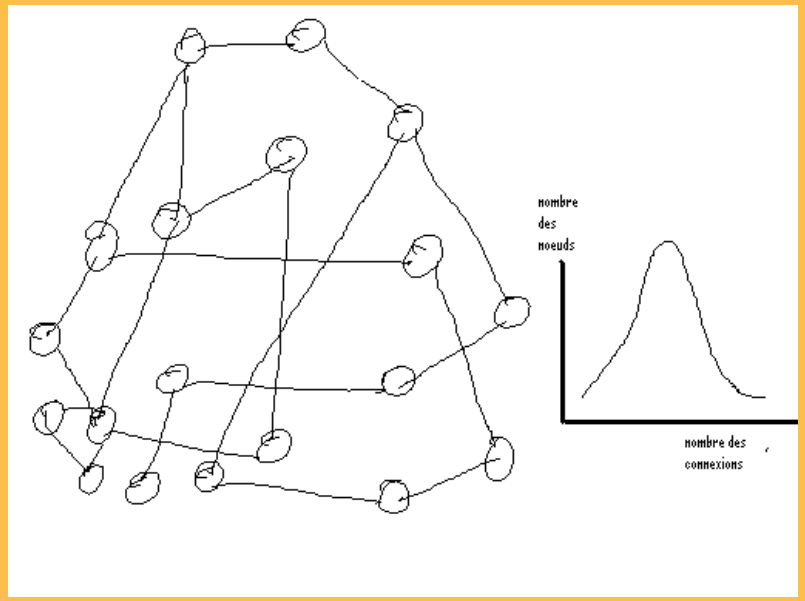


Figure 1. Watts-Strogatz model interpolates between a regular lattice *(left)* and a random graph *(right)*. Randomly rewiring just a few edges *(center)* reduces the average distance between nodes, *L*, but has little effect on the clustering coefficient, *C*. The result is a "small-world" graph.

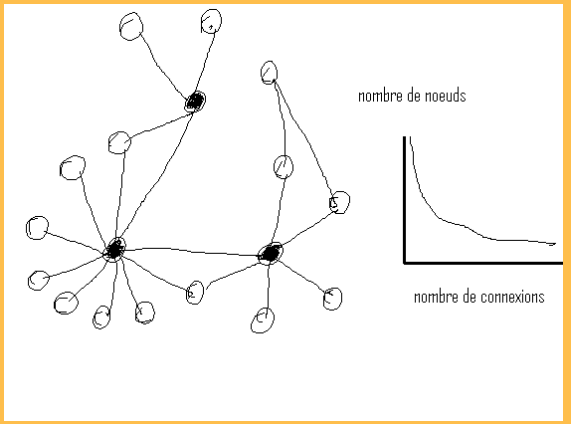
Mais les réseaux ne sont pas homogènes !



With aggregates

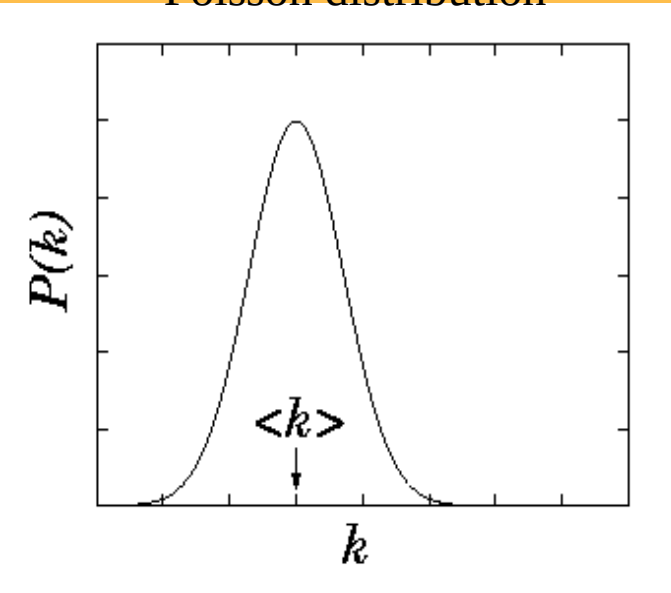


Random

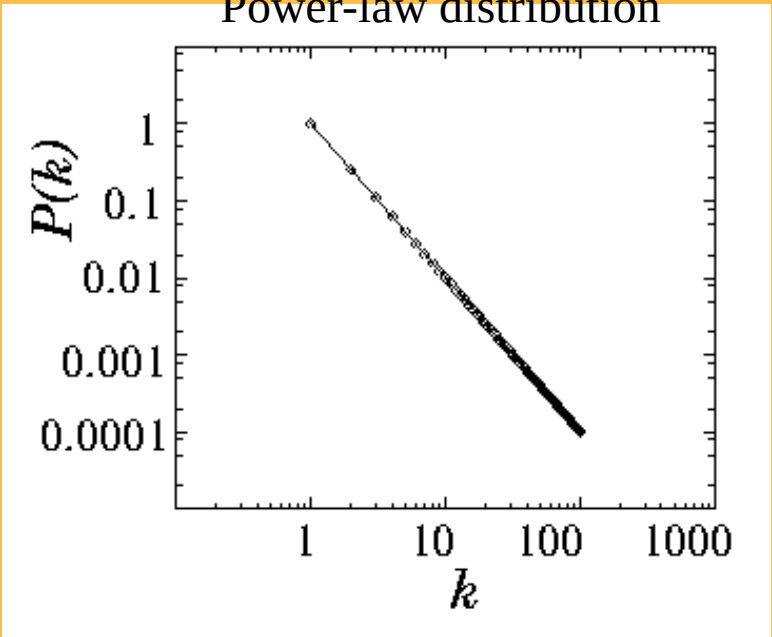


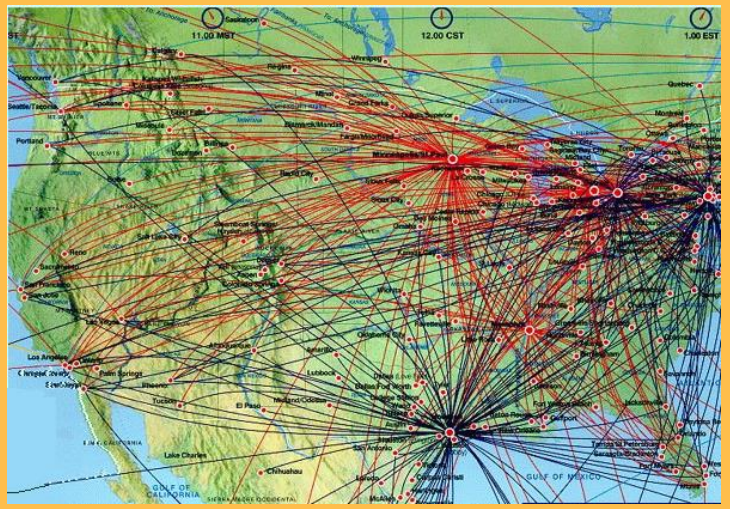
Scale-Free

Poisson distribution



Power-law distribution

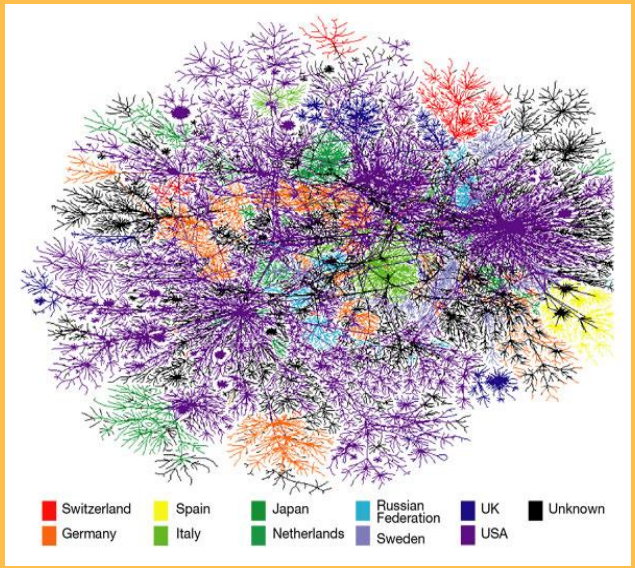


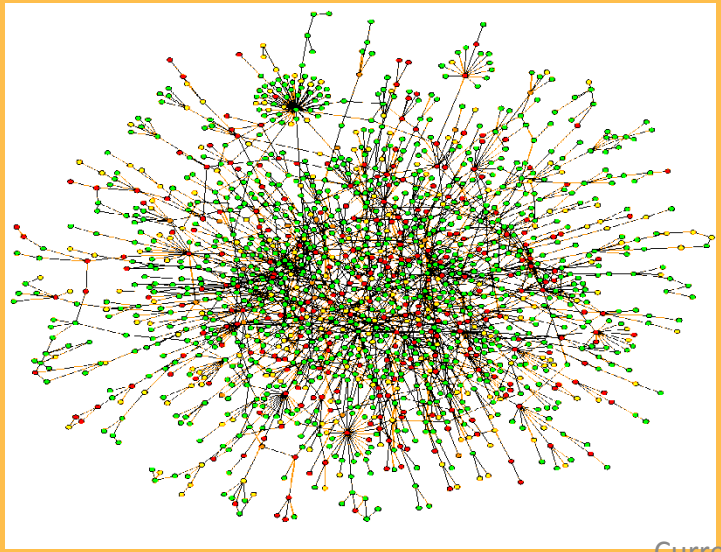


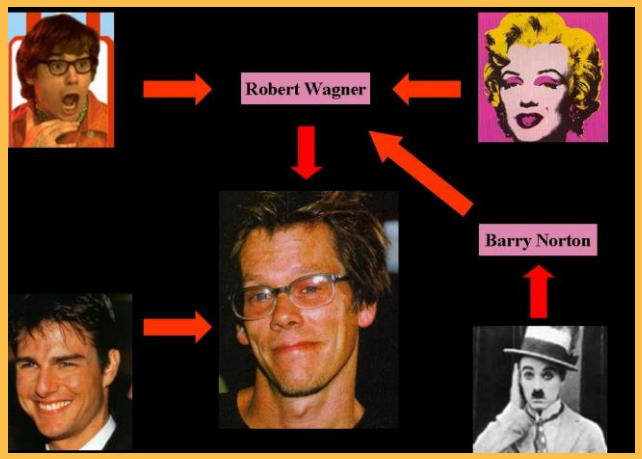
Exponential Network

Scale-free Network

Babarasi (début des années 2000)

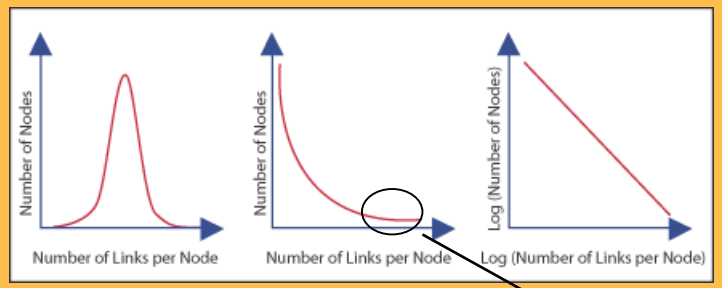






Les réseaux sociaux sont « scale-free »:

$$P(k) \sim k^{-\gamma}$$



connecteurs

WWW (in)	Internet	Actor	Citation index	Sex Web	Cellular network	Phone call network	linguistics
$\gamma = 2.1$	$\gamma = 2.5$	$\gamma = 2.3$	$\gamma = 3$	$\gamma = 3.5$	$\gamma = 2.1$	$\gamma = 2.1$	$\gamma = 2.8$

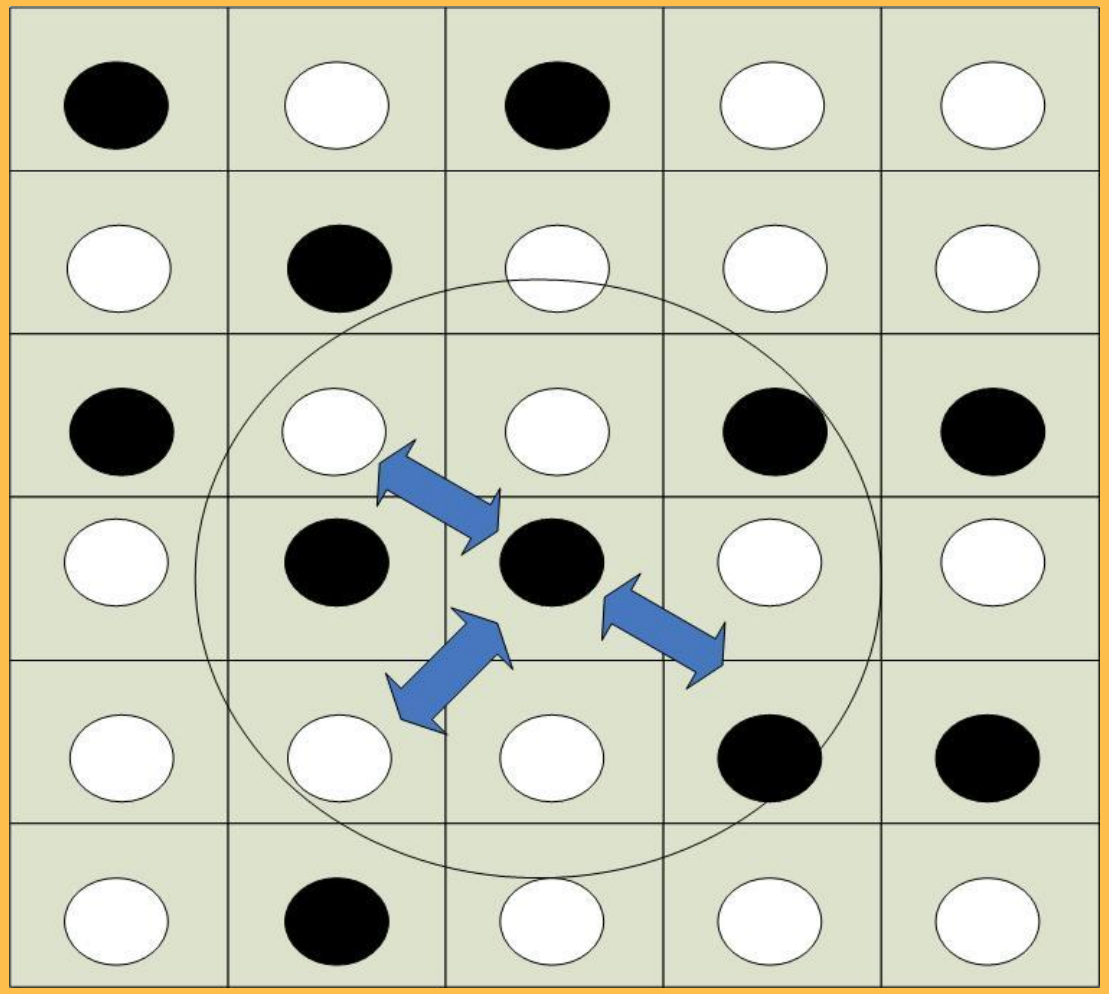
2) Emergence of cooperation

Game theory and prisoner dilemma

Agent1/Agent2	Cooperate	Defect
Cooperate	(1,1)	(0, 1+x)
Defect	(1+x,0)	(0,0)

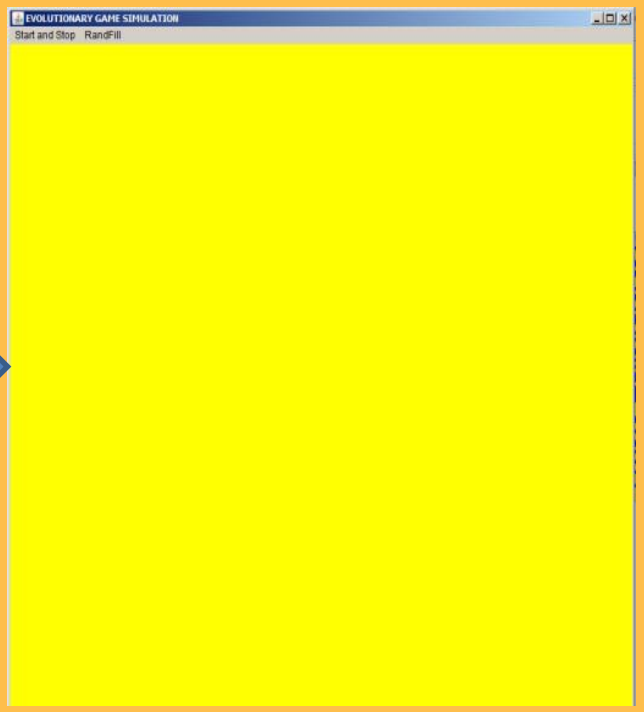
The best strategy (Nash equilibrium) is to defect but doing so you miss the Pareto solution (global cooperation).

Evolutionary Games: Mimetism

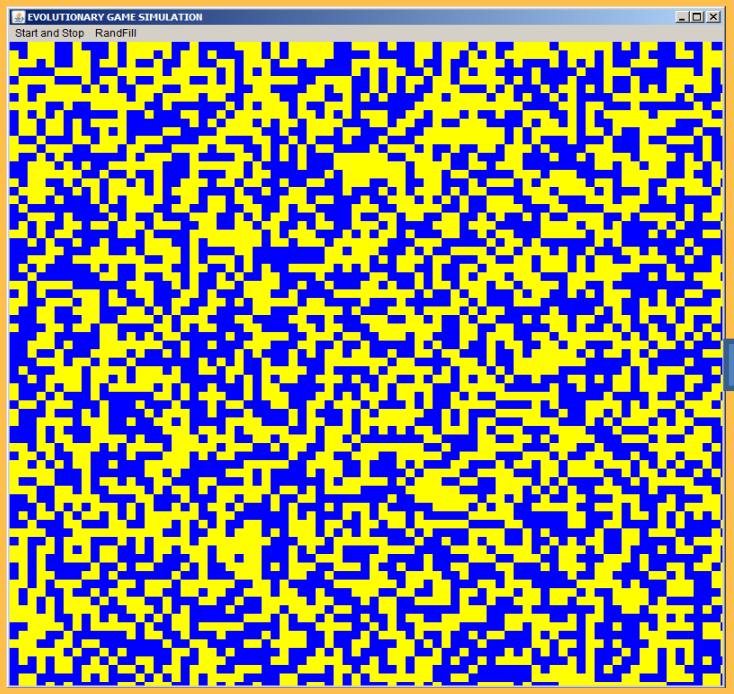


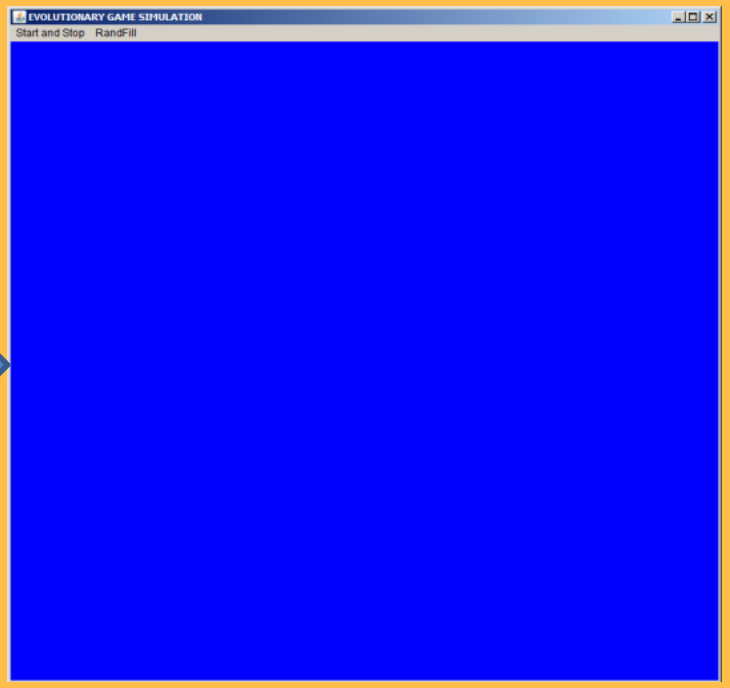
X = 0.30


EVOLUTIONARY GAME SIMULATION
Start and Stop
RandFill

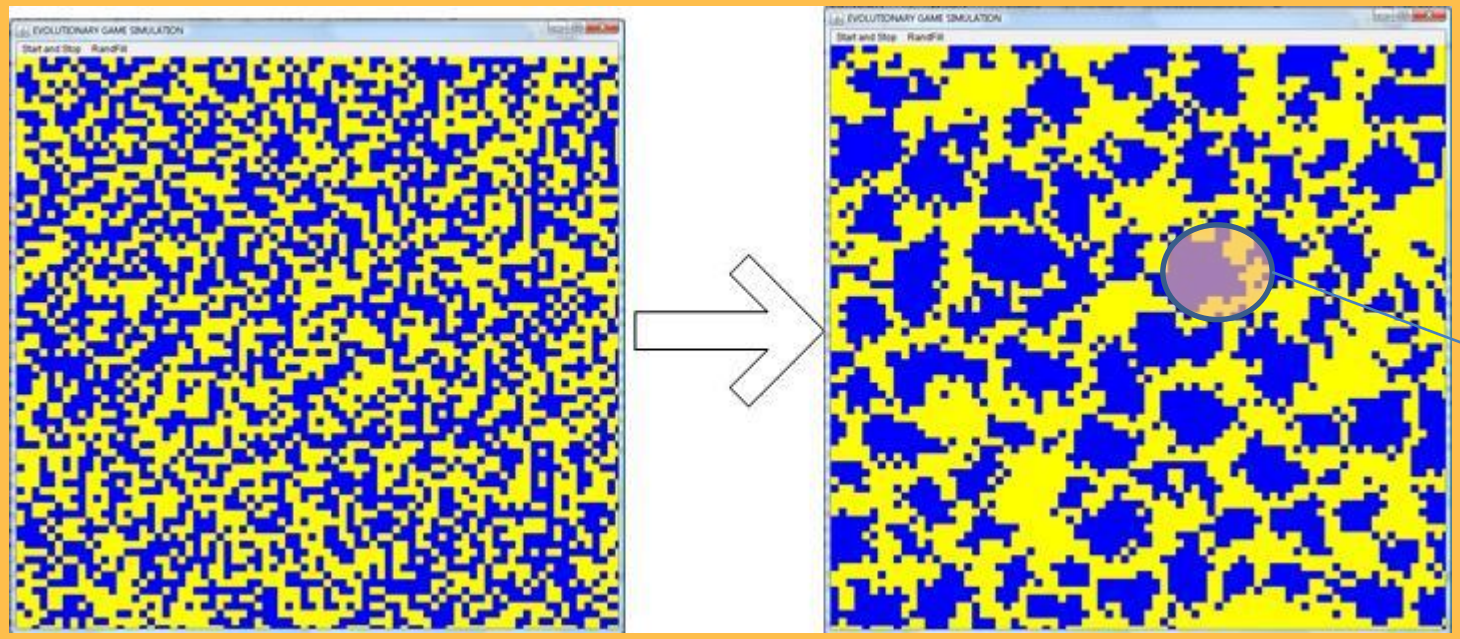

EVOLUTIONARY GAME SIMULATION
Start and Stop
RandFill

X = -0.1


EVOLUTIONARY GAME SIMULATION
Start and Stop
RandFill


EVOLUTIONARY GAME SIMULATION
Start and Stop
RandFill

But for intermediary values X: 0.15

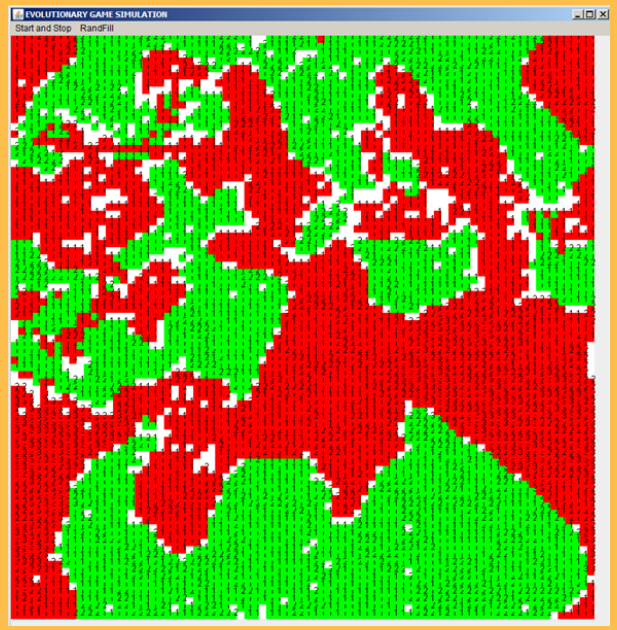


Cluster of cooperators

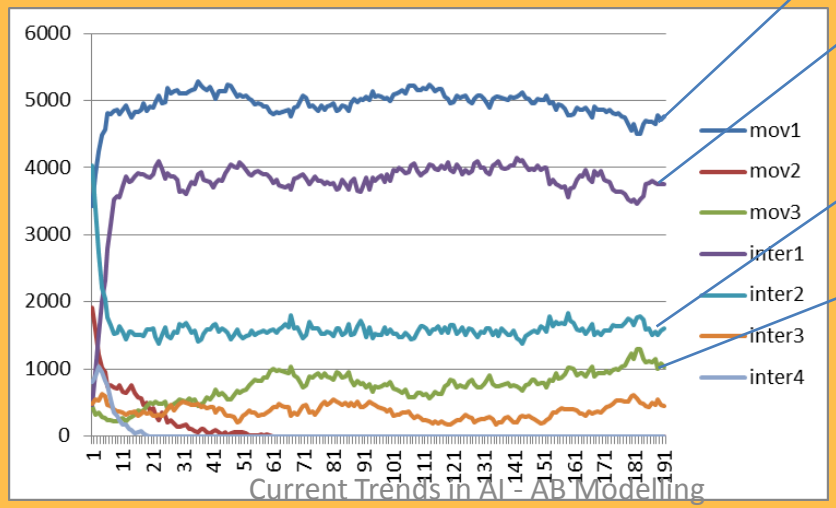
In between Schelling and Maynard-Smith

X=0.10 -> An intermediary subtle world

Final configuration



Evolutionary activity



Stay

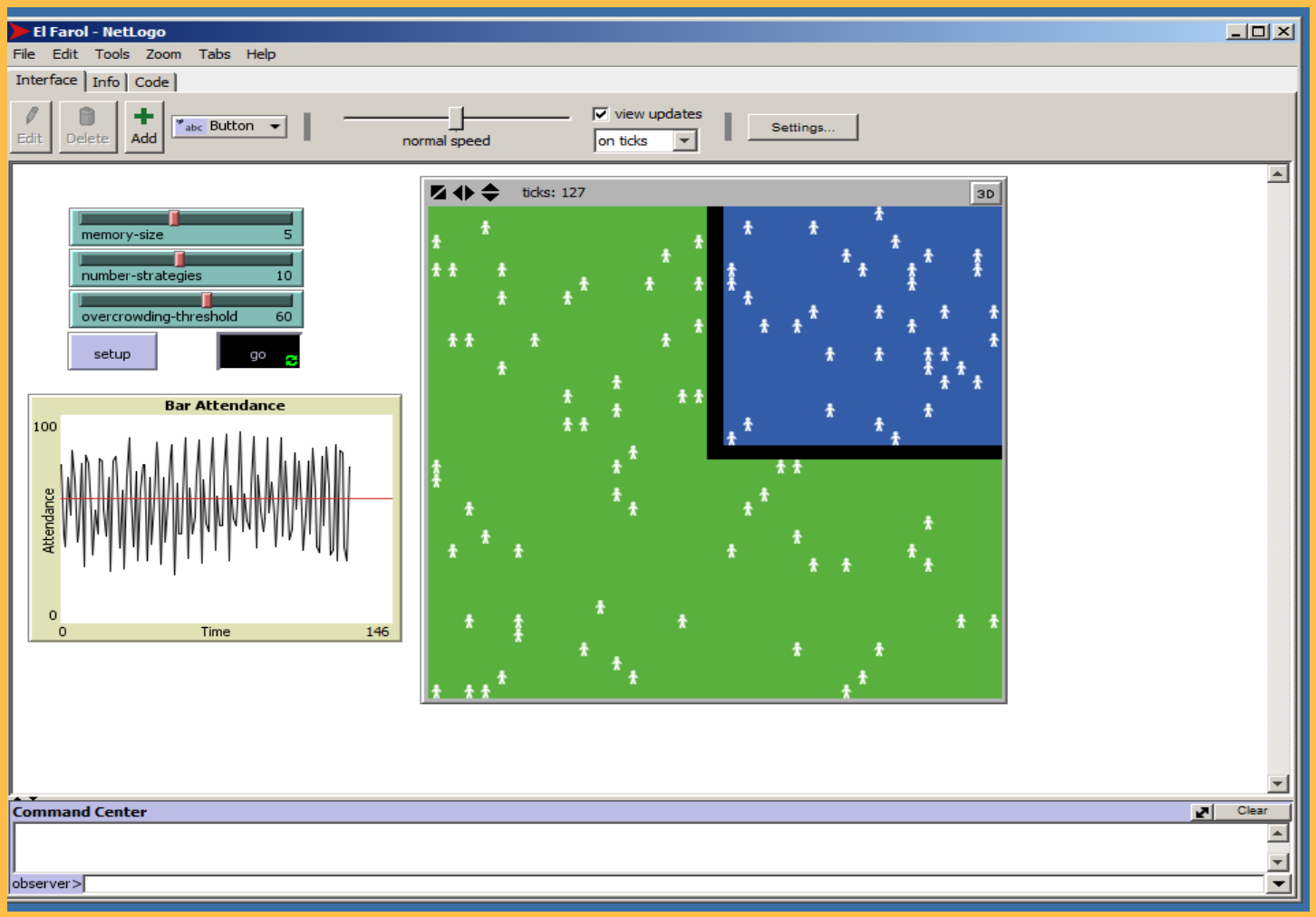
Cooperate with all

Cooperate with same color

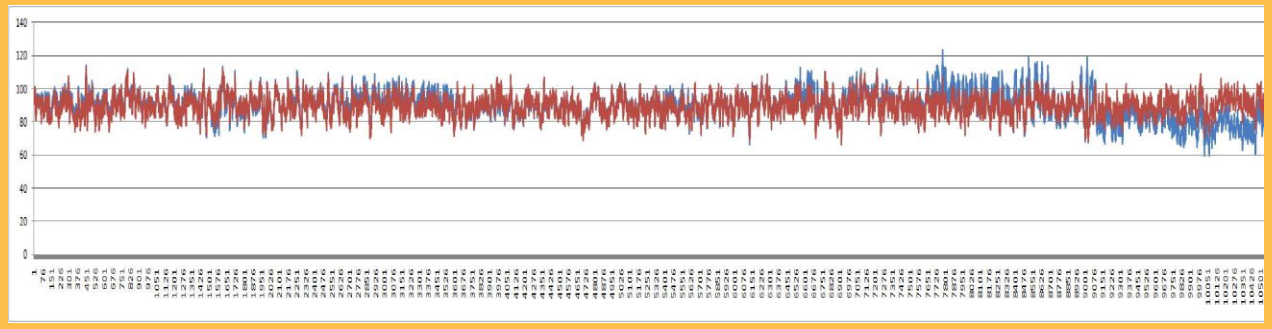
Communitarian movement

- Cooperation emerges by regrouping the cooperators
  - Tit-for-tat
  - Scale-free network
  - Spatial regrouping
  - Group Selection
  - Communitarian segregation

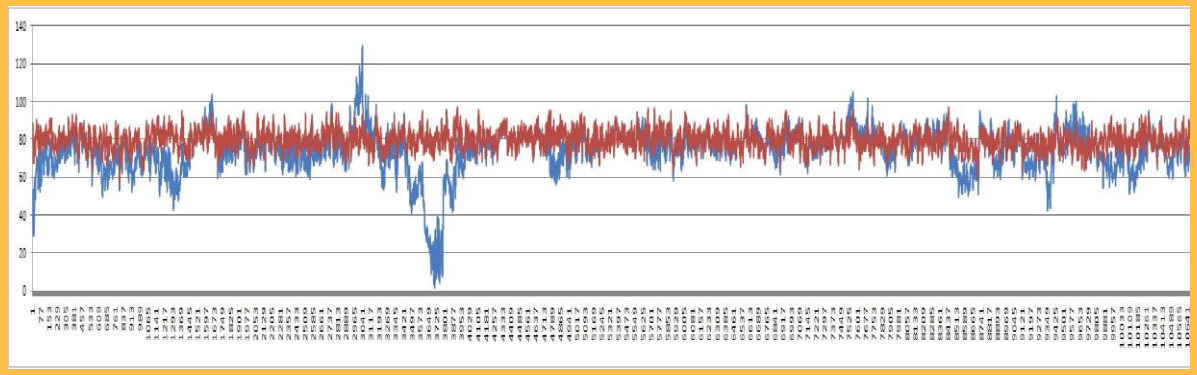
3) Market self-regulation
The El Farol Bar


El Farol - NetLogo
File Edit Tools Zoom Tabs Help
Interface Info Code
Edit Delete Add
Button
normal speed
view updates
on ticks
Settings...
memory-size 5
number-strategies 10
overcrowding-threshold 60
setup
go
Bar Attendance
100
Attendance
0
0
Time
146
ticks: 127
3D
Command Center
Clear
observer>

Same approach for market traders

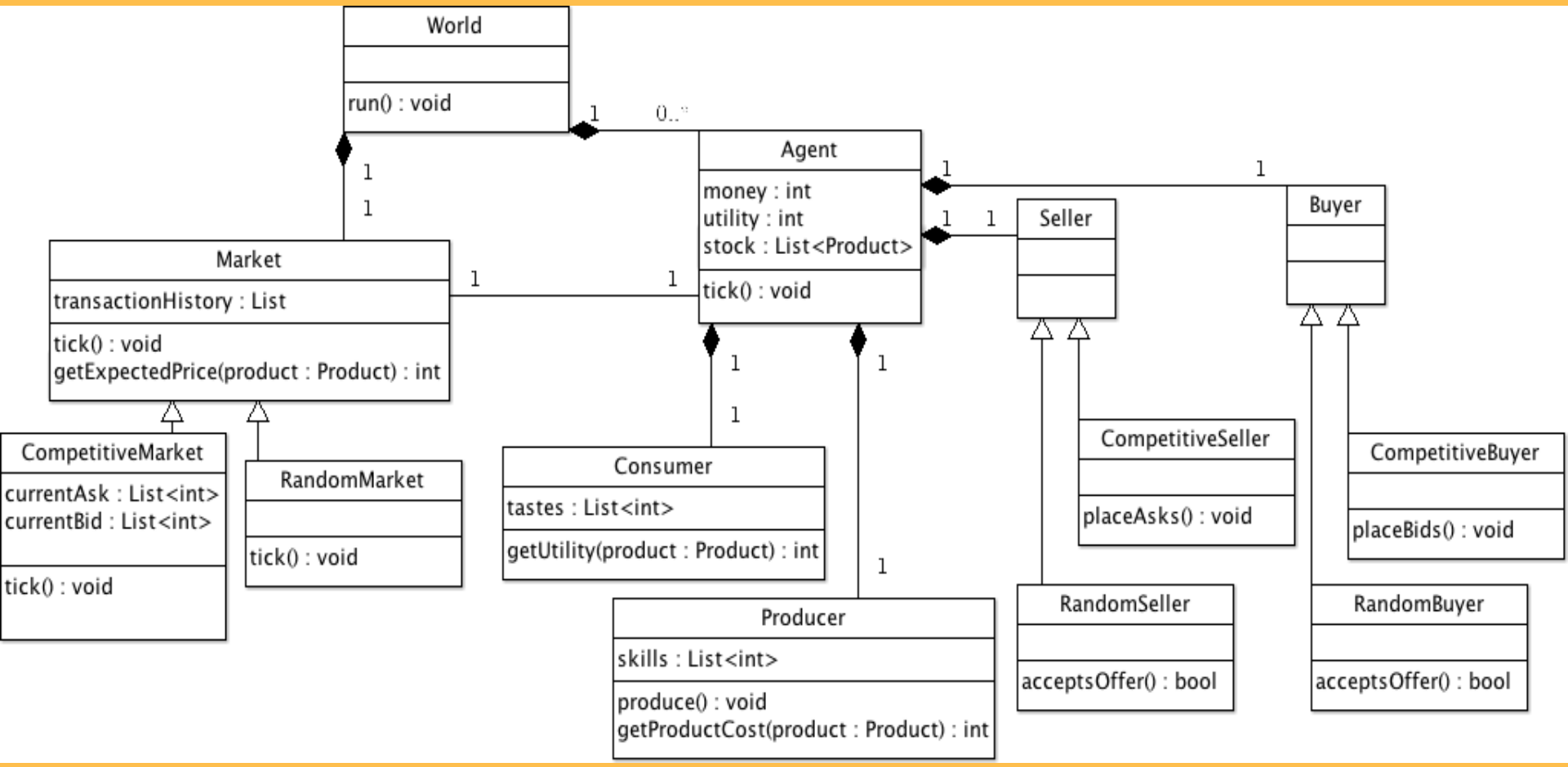


VS

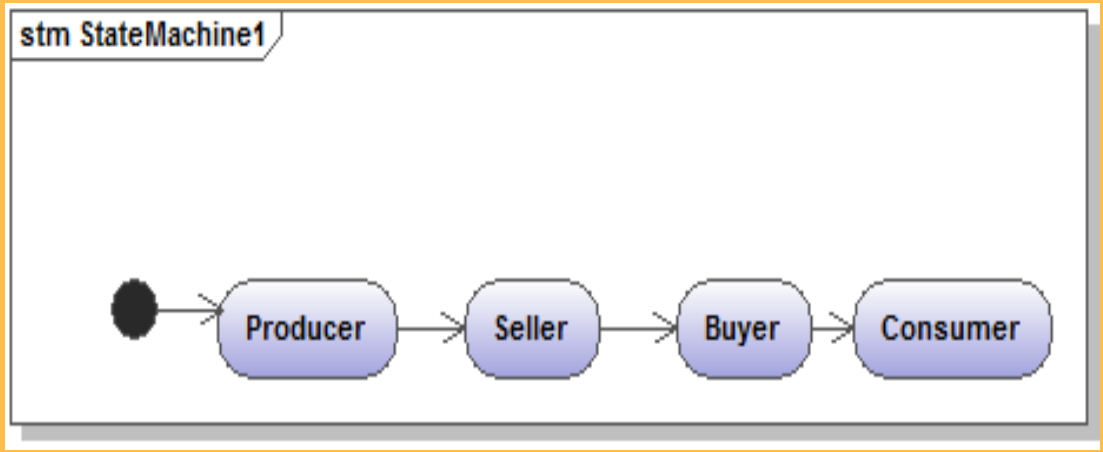


4) The dilemma equality/efficiency

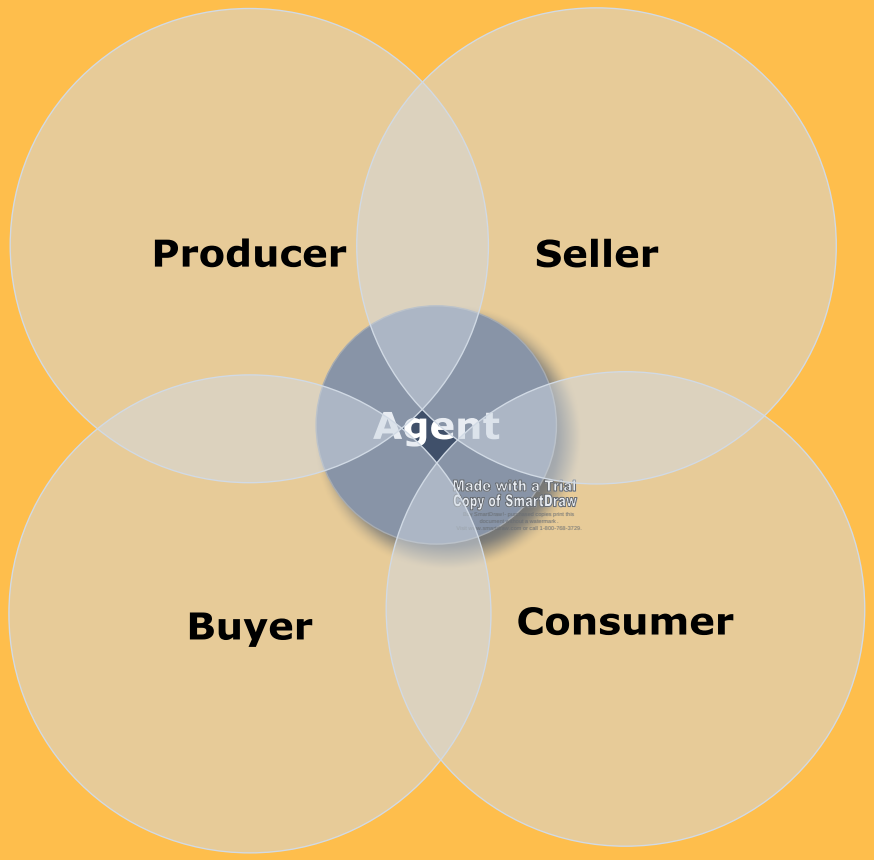
Class Diagram



Agent’s behaviour

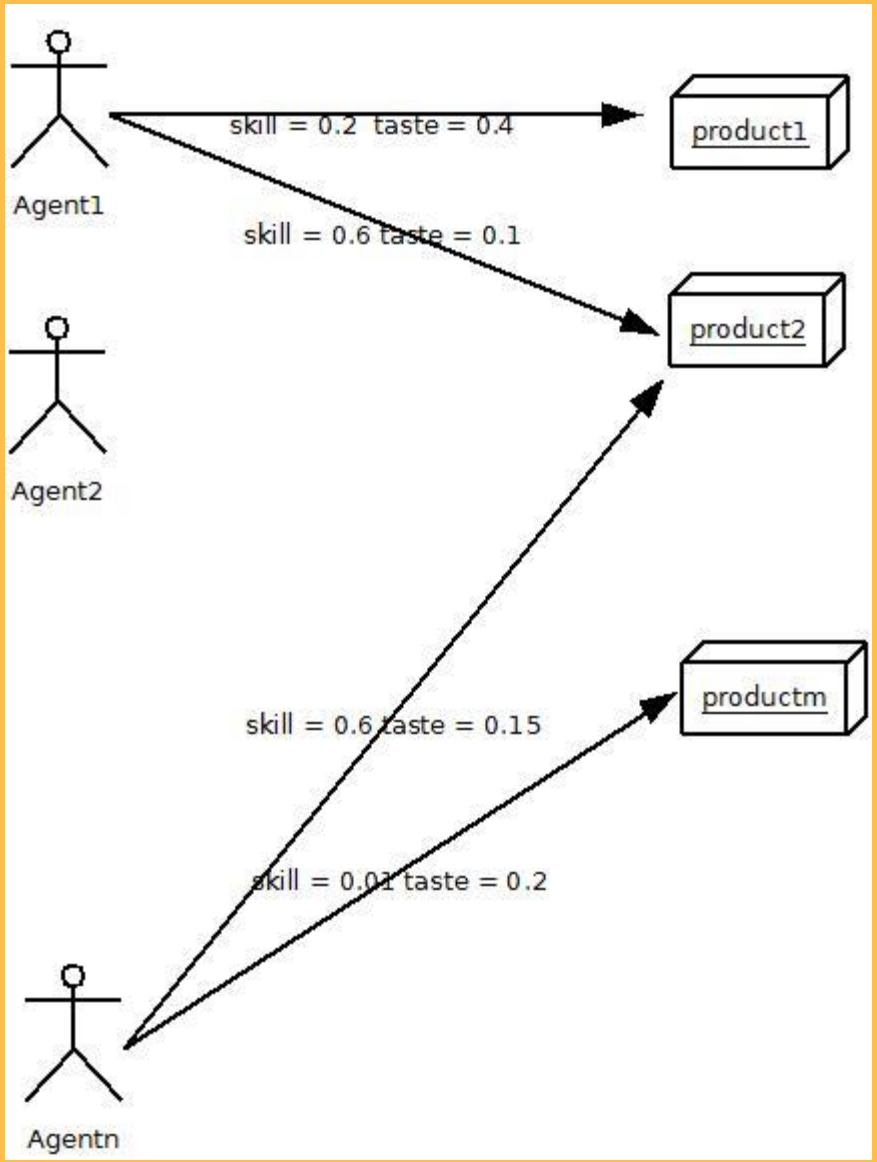


Agent: welfare - money - tastes - skills



Agents have initial money that they spend by producing and increase welfare by consuming.

Agents have tastes and skills that are random vectors of products.



Skills → Production cost, money expenses and seller's choice.

Tastes → Welfare increase by consumption and buyer's choice

At each time step

- A randomly chosen agent produces
- A randomly chosen agent sells
- A transaction occurs → Competitive or random
- A randomly chosen agent buys and consumes.
- If no transaction turns out to be possible on account of an impossible pairing: seller/buyer:
  - >>> MARKET FAILURE !!!!!!
  - >>> HAYEK's EFFICIENCY

Consumer

- The consumer immediately consumes what he has bought. His welfare increases by consuming according to his taste.
- Two simulations: One without diminishing marginal utility and one with.

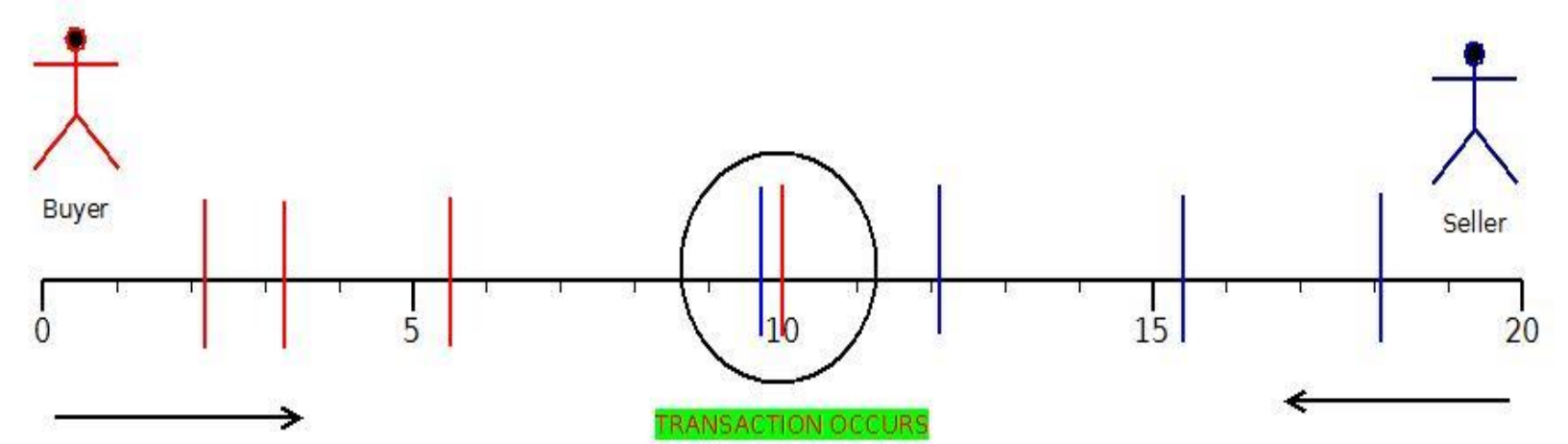
Producer

- The producer first decides which product to produce
- Two factors: his skills and the average price of the last m transactions
- After x productions of a same product, his skill increases.
- Then all skills are renormalized

Random seller/buyer

- Random seller places an ask on a random product
- A random buyer reacts
  - If his reservation price is above the seller offer: the transaction occurs.
  - He proposes a random price above the seller offer
- The price is randomly fixed in between both offers.

Competitive buyer/seller: Double auction market



Competitive seller places a better ask for the most profitable product (thresholded by his production price)
Competitive buyer places a better bid for the most desired product (thresholded by his reservation price (tastes)).
If the two offers cross -> The transaction occurs (price = seller's)

Main results

- Four key metrics:
  1. Agent utility (aggregated and gini)
  2. Agent money (aggregated and gini)
  3. Added value (difference between production price and transaction price)
  4. MARKET FAILURES: When no transaction turns out to be possible

First simulations: 50 agents, 10 products, 50000 time steps

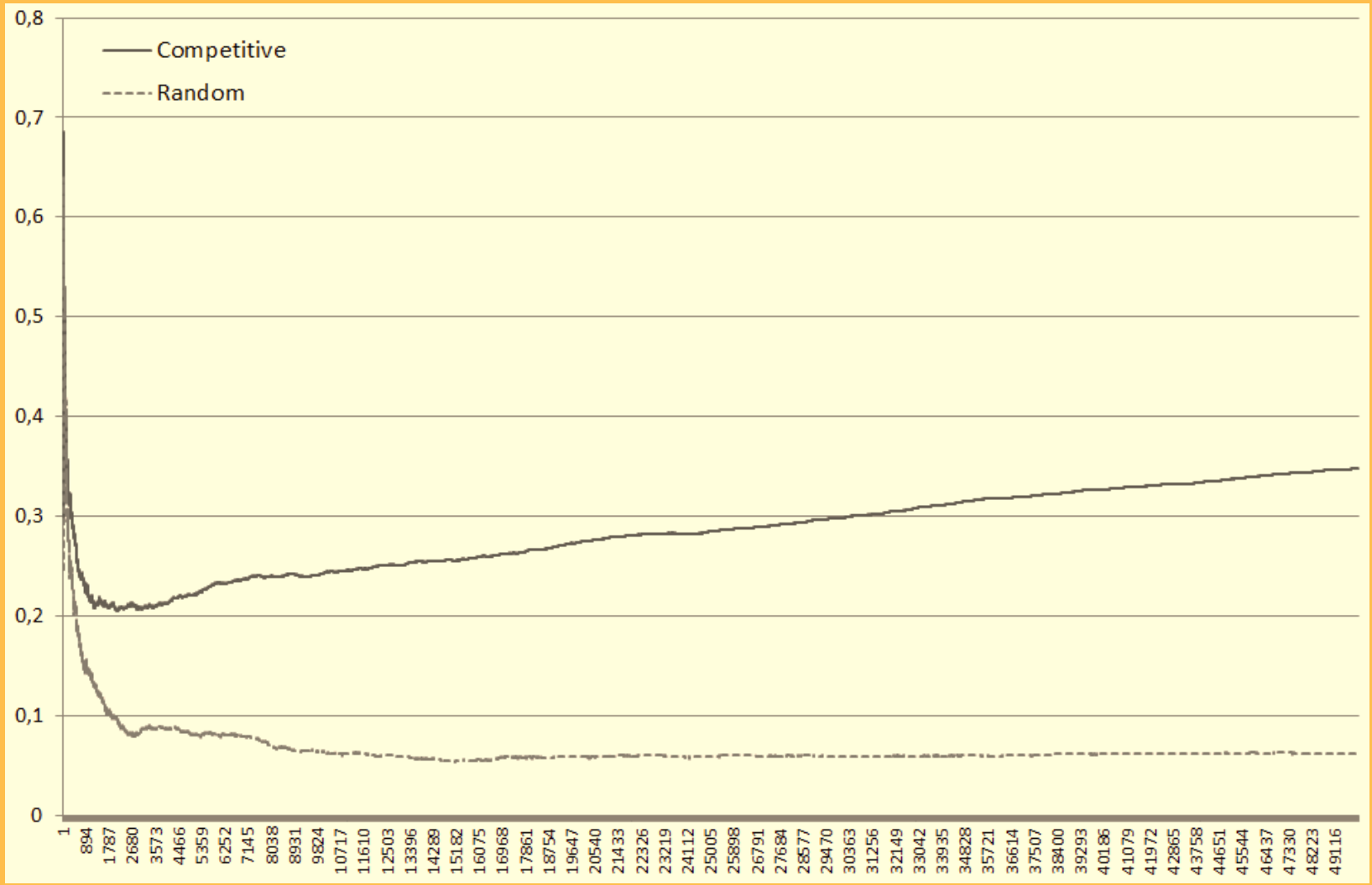
- Each agent is endowed with 500 units of money. No budget constraint.
- Number of past transactions to memorize = 100
- No utility marginal decrease:
  - *Random Market: Total Utility: 5390, Total Money: 24312, Gini Utility: 0.04, Gini Money: 0.007, MF: 0*
  - *Competitive Market: Total Utility: 9755, Total Money: 24491, Gini Utility: 0.27, Gini Money: 0.08, MF:0*
- Utility Marginal decrease:
  - *Random Market: Total Utility: 5152, Total Money: 24244, Gini Utility: 0.02, Gini Money: 0.007, MF: 0*
  - *Competitive Market: Total Utility: 5424, Total Money: 24488, Gini Utility: 0.042, Gini Money: 0.004, MF:0*
- *Main results: In case of no budgetary constrain, just taste differences increase inequality by sellers/buyers pairing in competitive markets*

Influence of the budget constraint in the competitive market.

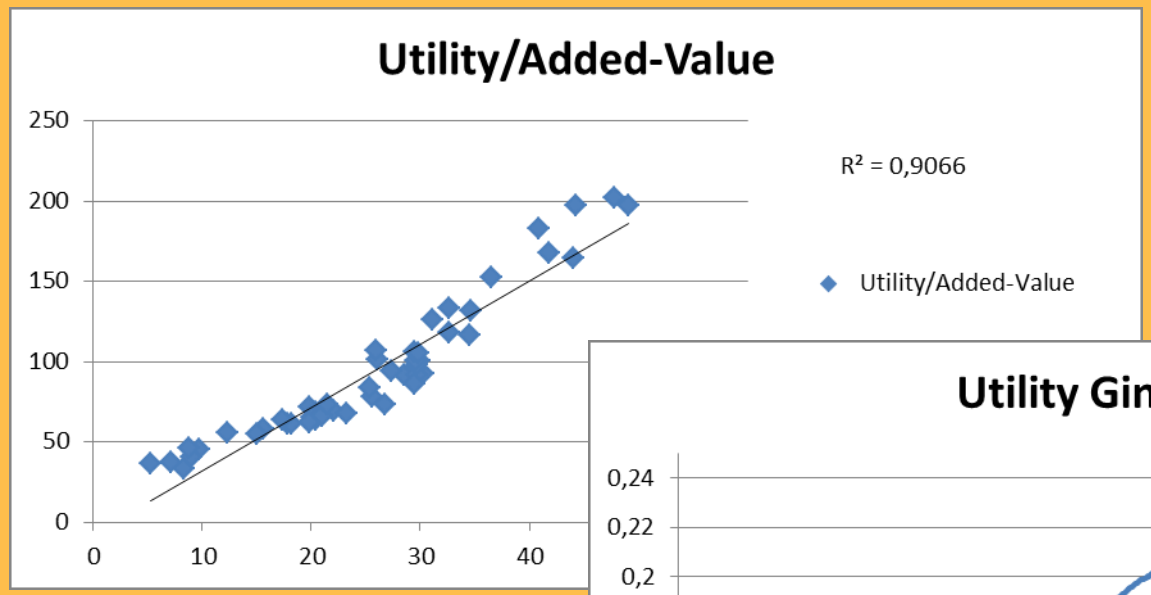
Money	100	80	60	50	25	20	15	10
Utility	5465	5340	5464	5452	5433	5401	5330	5246
Money	4182	3275	2093	1735	494	284	83	17
Ad. Val.	3680	3720	3264	3380	2675	2400	1817	1424
G(Util)	0.05	0.061	0.077	0.070	0.088	0.12	0.16	0.25
G(Mon)	0.006	0.007	0.013	0.010	0.016	0.017	0.014	0.08
G(AV)	0.08	0.092	0.11	0.10	0.13	0.15	0.17	0.20
MF	0	0	0	0	0	26	270	914

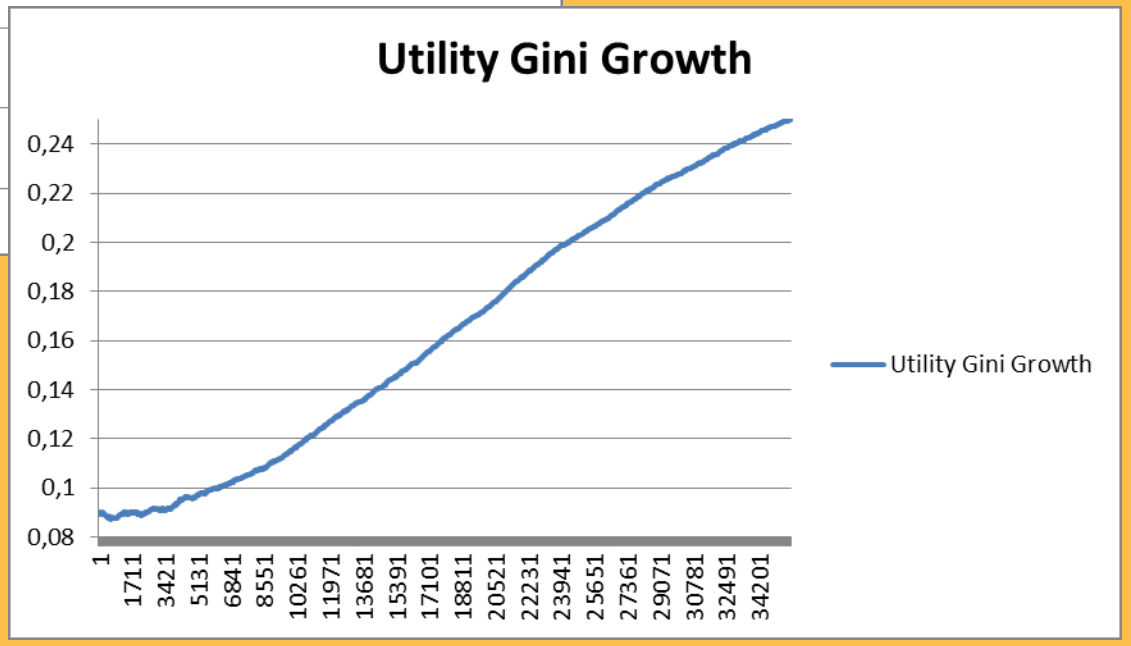
The random market can only work until budget constraint of 50
Gini index increases while the initial budget decreases.

Gini index


Competitive
Random
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1
894
1787
2680
3573
4466
5359
6252
7145
8038
8931
9824
10717
11610
12503
13396
14289
15182
16075
16968
17861
18754
19647
20540
21433
22326
23219
24112
25005
25898
26791
27684
28577
29470
30363
31256
32149
33042
33935
34828
35721
36614
37507
38400
39293
40186
41079
41972
42865
43758
44651
45544
46437
47330
48223
49116

Gini index growing in case of small initial budget





Conclusions: Comparison lottery/concurrence

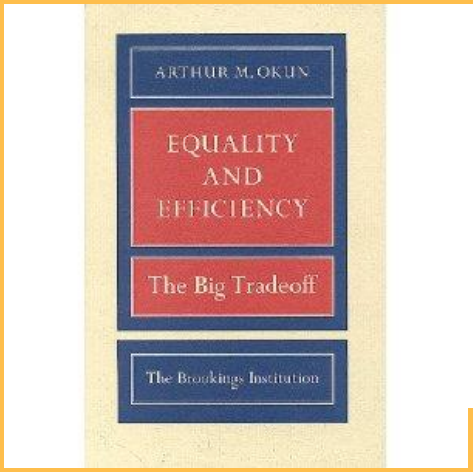
Lottery

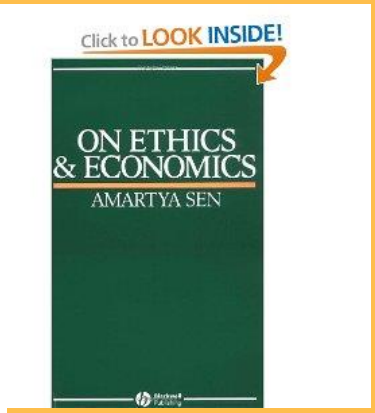
- Low Gini → More equality
- Low aggregate utility → Less efficient
- Prices don't inform as well

Concurrence

- High Gini → Less equality
- High aggregate utility → More efficient
- Prices inform the producers

Fondamental economy dilemma





Solutions: Redistributions (but Okun), regulation (state), more randomness in economy -> Social economy (barter)

Randomness in competition

- Random selection of 10 out of 17 contrade
- Random assignement of horse to contrade
- Random initial placement of horses

Conclusions

1. Only computer simulations allow to detect and to practice the « weak emergence ».
2. Today « Big Data » and the Web allow to validate and calibrate the models
3. A better and finer understanding of collective, emergent phenomena allow to better predict and, above all, to better regulate them (such as the crowds).