Cognitive and Experimental Economics
Economic Decisions and Bounded Rationality

Cognitive or behavioral economics? Brain scanning, experiments, agent-based simulation for the interaction among psychology, economics and the other social sciences

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The talk:

(a) a general introduction

(b) my current researches

Cognitive economics or behavioral economics:

the first part of the title

From en.wikipedia.org, searching for "behavioral economics"

Behavioral economics uses social, cognitive and emotional factors in understanding the economic decisions of individuals and institutions performing economic functions (…)

The fields are primarily concerned with the bounds of rationality (selfishness, self-control) of economic agents. Behavioral models typically integrate insights from psychology with neo-classical economic theory.

From en.wikipedia.org, searching for "cognitive economics"

Did you mean: cognitive ergonomics (?)

Results 1–20 of 734 for cognitive economics

Behavioral economics (section Economics)

Behavioral economics uses social, cognitive and emotional factors in understanding the economic decisions of individuals and ...

From it.wikipedia.org, searching for "economia cognitiva"

Economia cognitiva

(Questa voce sull'argomento economia è solo un abbozzo. Contribuisci a migliorarla secondo le convenzioni di Wikipedia e i suggerimenti del progetto di riferimento.)

L'economia cognitiva è una nuova branca dell'economia, che si è sviluppata in ambito accademico dopo l'attribuzione del premio Nobel per l'economia a Vernon Smith e a Kahneman nel 2003.

Alla base dell'economia cognitiva è il superamento del principio cardine dell'economia neoclassica, la razionalità degli agenti economici, nonché una critica della lontananza tra il mondo empirico e i modelli teorici proposti dall'economia neoclassica.

Brain scanning, experiments, agent-based simulation for the interaction among psychology, economics and the other social sciences :

the second part of the title

The “cognitive suite”:

•interdisciplinary approach

•search for the links between (i) information gathering and processing and (ii) the emergence of preferences and decisions

The difference between the behavioral and the cognitive approaches is evident in model building, mainly in the perspective of Agent Based Models (ABMs)

Anyway, the distance between the two approaches is someway fuzzy and cooperation is prominent, being neuroeconomics and experiments two sound bridges

Basics: models for what?

Rosenblueth and Wiener’s 1945 paper, “The Role of Models in Science” (°), as a “manual” from the founders of cybernetics.

(p. 317) A distinction has already been made between material and formal or intellectual models. A material model is the representation of a complex system by a system which is assumed simpler and which is also assumed to have some properties similar to those selected for study in the original complex system. A formal model is a symbolic assertion in logical terms of an idealized relatively simple situation sharing the structural properties of the original factual system.
Material models are useful in the following cases. a) They may assist the scientist in replacing a phenomenon in an unfamiliar field by one in a field in which he is more at home.

(…) b) A material model may enable the carrying out of experiments under more favorable conditions than would be available in the original system.

(°) Philosophy of Science, Vol. 12, No. 4 (Oct., 1945), pp. 316-321

Rosenblueth and Wiener's 1945 paper, "The Role of Models in Science" , as a "manual" from the founders of cybernetics.

(p. 319) It is obvious, therefore, that the difference between open-box and closed-box problems, although significant, is one of degree rather than of kind. All scientific problems begin as closed-box problems, i.e., only a few of the significant variables are recognized. Scientific progress consists in a progressive opening of those boxes. The successive addition of terminals or variables, leads to gradually more elaborate theoretical models: hence to a hierarchy in these models, from relatively simple, highly abstract ones, to more complex, more concrete theoretical structures.

A comment: this is the main role of simulation models: building material models as artifacts running into a computer, having always in mind to go toward "more elaborate theoretical models":

Facts => Simulations => Theory

In a historical perspective

Keynes [1924], Collected Writings, X, 1972, 158n

Professor Planck, of Berlin, the famous originator of the Quantum Theory, once remarked to me that in early life he had thought of studying economics, but had found it too difficult! Professor Planck could easily master the whole corpus of mathematical economics in a few days. He did not mean that! But the amalgam of logic and intuition and the wide knowledge of facts, most of which are not precise, which is required for economic interpretation in its highest form is, quite truly, overwhelmingly difficult for those whose gift mainly consists in the power to imagine and pursue to their furthest points the implications and prior conditions of comparatively simple facts which are known with a high degree of precision.

A comment: Again, the confrontation between the material model (the artifact of the system) that we need to build taking in account randomness, heterogeneity, continuous learning in repeated trials and errors processes and the "simple" theoretical one.

Quoting a paper of Arthur, forthcoming (°)

(…) a second theme that emerged was that of making models based on more realistic cognitive behavior. Neoclassical economic theory treats economic agents as perfectly rational optimizers. This means among other things that agents perfectly understand the choices they have, and perfectly assess the benefits they will receive from these.

(…) Our approach, by contrast, saw agents not as having perfect information about the problems they faced, or as generally knowing enough about other agents' options and payoffs to form probability distributions over these. This meant that agents need to cognitively structure their problems—as having to 'make sense' of their problems, as much as solve them.

(°) W. Brian Arthur, Complexity, the Santa Fe Approach, and Nonequilibrium Economics, in History of Economic Ideas, 2010, 2?

In complexity terms, following Holt, Barkley Rosser and Colander (2010), The Complexity Era in Economics (°),we go close to material models also if we take into account the details of complexity:

(p. 5) Since the term complexity has been overused and over hyped, we want to point out that our vision is not of a grand complexity theory that pulls everything together. It is a vision that sees the economy as so complicated that simple analytical models of the aggregate economy—models that can be specified in a set of analytically solvable equations—are not likely to be helpful in understanding many of the issues that economists want to address.

(°) Middlebury College Economics Discussion Paper 10-01, http://sandcat.middlebury.edu/econ/repec/mdl/ancoec/1001.pdf

Moving to models

We can now move to models, the material models of cybernetics founders, or the computational artifacts of the agent based simulation perspective.

Following Ostrom (1988), and to some extent, Gilbert and Terna (2000), in social science, we traditionally build models as simplified representations of reality in two ways:

(i)verbal argumentation and

(ii)mathematical equations, typically with statistics and econometrics.

(iii)computer simulation, mainly if agent-based.

Computer simulation can combine the extreme flexibility of a computer code – where we can create agents who act, make choices, and react to the choices of other agents and to modification of their environment – and its intrinsic computability.

However, reality is intrinsically agent-based, not equation-based.

At first glance, this is a **strong criticism**. Why reproduce social structures in an agent-based way, following (iii), when science applies (ii) to describe, explain, and forecast reality, which is, per se, too complicated to be understood?

The main reply is again that we can, with agent-based models and simulation, produce artifacts (the 'material model') of actual systems and "play" with them, i.e., showing consequences of perfectly known ex-ante hypotheses on agent designs and interactions; then we can apply statistics and econometrics to the outcomes of the simulation and compare the results with those obtained by applying the same tests to actual data.

In this view, simulation models act as a sort of magnifying glass that may be used to better understand reality.

Negative side: agent-based simulation models have severe weaknesses, primarily arising from:

•The difficulty of fully understand them without studying the program used to run the simulation;

•The necessity of carefully checking computer code to prevent generation of inaccurate results from mere coding errors;

•The difficulty of systematically exploring the entire set of possible hypotheses in order to infer the best explanation. This is mainly due to the inclusion of behavioral rules for the agents within the hypotheses, which produces a space of possibilities that is difficult if not impossible to explore completely.

Some replies:

- Swarm (www.swarm.org), a project that started within the Santa Fe Institute and that represents a milestone in simulation;

- Swarm has been highly successful, being its protocol intrinsically the basis of several recent tools; for an application of the Swarm protocol to Python, see my SLAPP, Swarm Like Agent Protocol in Python at http://eco83.econ.unito.it/slapp

- Many other tools have been built upon the Swarm legacy, such as Repast, Ascape, JAS and also by more simple, but extremely important tools, such as NetLogo and StarLogoTNG.

The strongest necessities:

(i) interdisciplinary researches

(ii) sound sources for our models

associazione italiana di scienze cognitive @ AISC-NET.IT

Rosaria Conte
Alberto Greco
Francesca Giardini

http://www.aisc-net.it/index.php

Sistemi intelligenti, il Mulino
Fondata da Domenico Parisi

http://www.mulino.it/edizioni/riviste/scheda_rivista.php?issn=1120-9550

A recent proposal

CIPESS

Centro Interuniversitario di Psicologia ed Economia Sperimentali e Simulative

First conference and preliminary information

http://www.psych.unito.it/csc/pdf/cipessconvegno2009.pdf

The strongest necessities:

(i) interdisciplinary researches

(ii) sound sources for our models

- Actual data within well specified frameworks
- Direct observations
- Experiments (Vernon Smith, Elinor Ostrom)
- Neurosciences (Colin Camerer, Jonathan D. Cohen, Rosaria Conte)

Elinor Ostrom, Revising theory in light of experimental findings (°)

[In his essay, (Vernon) Smith raises the question of] how to interpret subjects’ behavior when their actions are not consistent with accepted theory. He puzzles about the explanations given by some scholars that behavior in experiments contrary to theoretical predictions is explained due to confusion. There is no question that in some experiments the subjects have been confused. Slowly but surely, however, experimentalists are learning ever better techniques to be sure that the experimental instructions are clear and are pretested extensively prior to running a real experiment. The experiment itself is usually not started until after the subjects demonstrate understanding by answering quizzes and engaging in practice rounds. Subjects are usually encouraged to ask questions before an experiment starts so that the experimenter is clear that the subjects do understand the instructions.

(°) Journal of Economic Behavior & Organization 73 (2010) 68–72

Elinor Ostrom, Revising theory in light of experimental findings

If "confusion" means that subjects in some experiments are not thinking like conventional theory has posited, then this conclusion is important and appears to be correct. This does not mean, however, that the subjects are confused in the sense that they did not understand the experiment. We would be in a bit of a theoretical pickle if we simply argue that any behavior different than posited by the theory underlying an initial experimental design was due to subjects' confusion. This allows us to continue the theory even with considerable evidence contrary to it. Given some of the experiments on public goods that were conducted to clarify whether subjects understood the experiment or not (…), we can conclude that the totally self-interested theory of human behavior is not adequate to explain behavior in all public good and common-pool resource experiments as well as other social dilemmas.

Colin Camerer, George Loewenstein and Drazen Prelec (2005), Neuroeconomics: How neuroscience can inform economics (°)

Neuroscience uses imaging of brain activity and other techniques to infer details about how the brain works. The brain is the ultimate ‘black box’. The foundations of economic theory were constructed assuming that details about the functioning of the brain’s black box would not be known. This pessimism was expressed by William Jevons in 1871: *I hesitate to say that men will ever have the means of measuring directly the feelings of the human heart. It is from the quantitative effects of the feelings that we must estimate their comparative amounts*.

(°) Journal of Economic Literature: Volume 43, Issue 1, March 2005

and also in Sistemi intelligenti, 3/2004, *Neuroeconomia, ovvero come le neuroscienze possono dare nuova forma all'economia*

Colin Camerer, George Loewenstein and Drazen Prelec (2005), Neuroeconomics: How neuroscience can inform economics

(…)

But now neuroscience has proved Jevons' pessimistic prediction wrong; the study of the brain and nervous system is beginning to allow direct measurement of thoughts and feelings. These measurements are, in turn, challenging our understanding of the relation between mind and action, leading to new theoretical constructs and calling old ones into question. How can the new findings of neuroscience, and the theories they have spawned, inform an economic theory that developed so impressively in their absence?

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Why a new tool and why SLAPP (Swarm-Like Agent Based Protocol in Python) as a preferred tool?

- For didactical reasons, applying a such rigorous and simple object oriented language as Python
- To build models upon transparent code: Python does not have hidden parts or feature coming from magic, it has no obscure libraries
- **To use the openness of Python**
- **To apply easily the SWARM protocol**

The openness of Python (www.python.org)

- … going from Python to R
  (R is at http://cran.r-project.org/ ; rpy library is at http://rpy.sourceforge.net/)
- … going from OpenOffice (Calc, Writer, …) to Python and viceversa (via the Python-UNO bridge, incorporated in OOo)
- … doing symbolic calculations in Python (via http://code.google.com/p/sympy/)
- … doing declarative programming with PyLog, a Prolog implementation in Python (http://christophe.delord.free.fr/pylog/index.html)
- … using Social Network Analysis from Python; examples:
- Igraph library http://cneurocvs.rmki.kfki.hu/igraph/
- libsna http://www.libsna.org/
- pySNA http://www.menslibera.com.tr/pysna/

The SWARM protocol

What's SLAPP: basically **a demonstration that we can easily implement the Swarm protocol** [Minar, N., R. Burkhart, C. Langton, and M. Askenazi (1996), *The Swarm simulation system: A toolkit for building multi-agent simulations*. Working Paper 96-06-042, Santa Fe Institute, Santa Fe (*)] **in Python**

(*) http://www.swarm.org/images/b/bb/MinarEtAl96.pdf

Key points (quoting from that paper):

•*Swarm defines a structure for simulations, a framework within which models are built.*

•*The core commitment is to a discrete-event simulation of multiple agents using an object-oriented representation.*

•*To these basic choices Swarm adds the concept of the "swarm," a collection of agents with a schedule of activity.*

The SWARM protocol

An absolutely clear and rigorous application of the SWARM protocol is contained in the original SimpleBug tutorial (1996?) with ObjectiveC code and text by Chris Langton & Swarm development team (Santa Fe Institute), on line at http://ftp.swarm.org/pub/swarm/apps/objc/sdg/swarmapps-objc-2.2-3.tar.gz (into the folder "tutorial", with the texts reported into the README files in the tutorial folder and in the internal subfolders)

The same has also been adapted to Java by Charles J. Staelin (*jSIMPLEBUG, a Swarm tutorial for Java*, 2000), at http://www.cse.nd.edu/courses/cse498j/www/Resources/jsimplebug11.pdf (text) or http://eco83.econ.unito.it/swarm/materiale/jtutorial/JavaTutorial.zip (text and code)

At http://eco83.econ.unito.it/terna/slapp you can find the same structure of files, but now implementing the SWARM protocol using Python

The SWARM **protocol** as ***lingua franca*** in agent based simulation models

Have a look to Swarm basics

Swarm = a library of functions and a **protocol**

modelSwarm

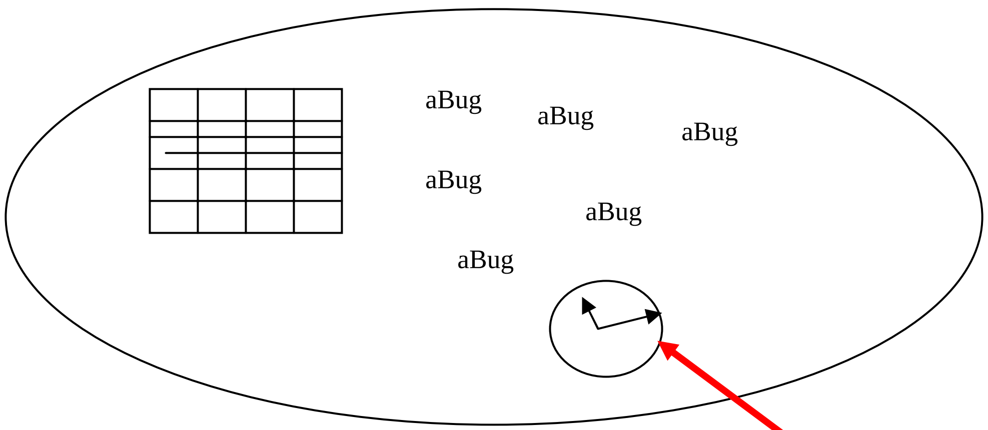
create objects

create actions

Bug
↓
aBug
↓
bugList

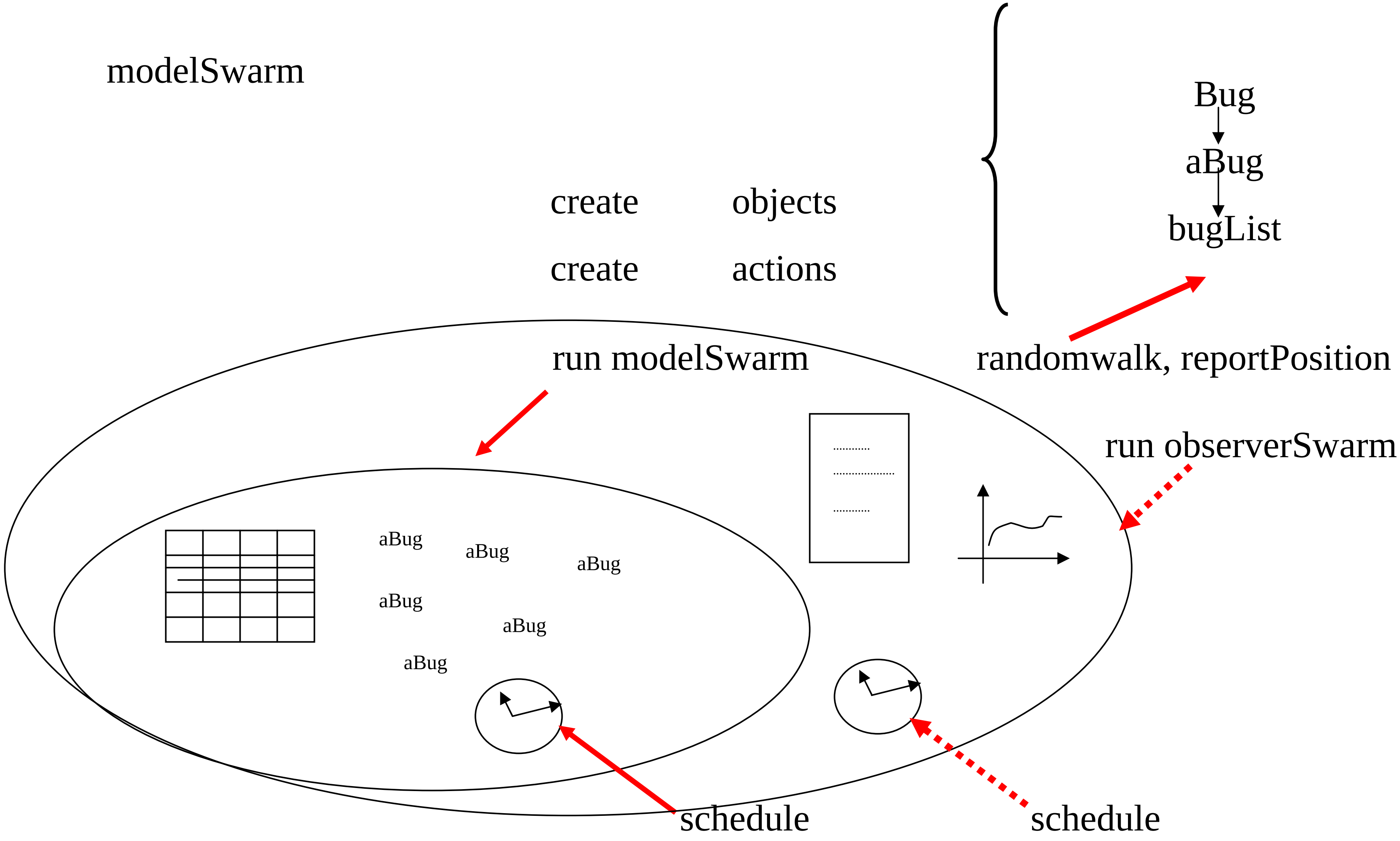
run modelSwarm

randomwalk,

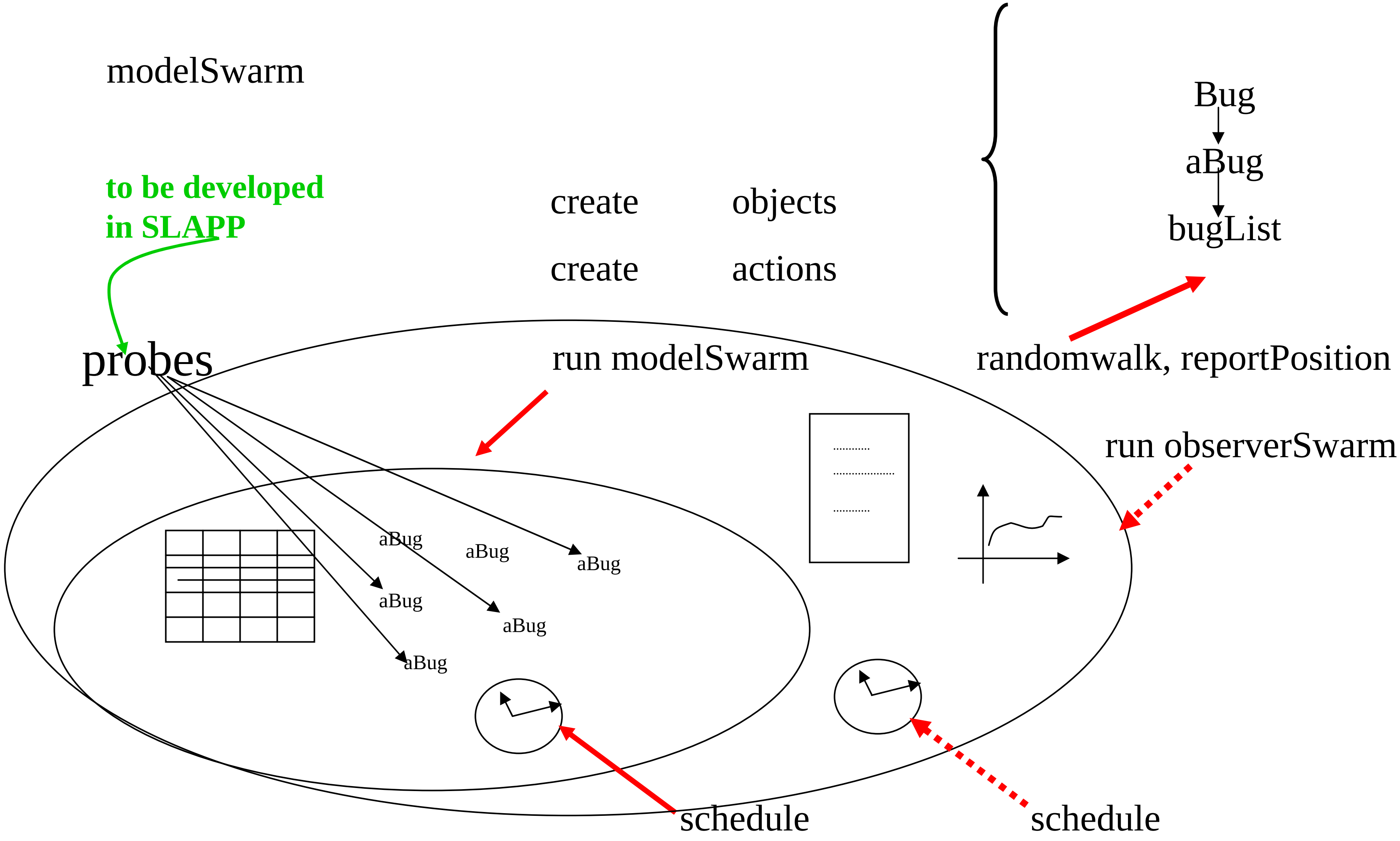


schedule

Swarm = a library of functions and a **protocol**

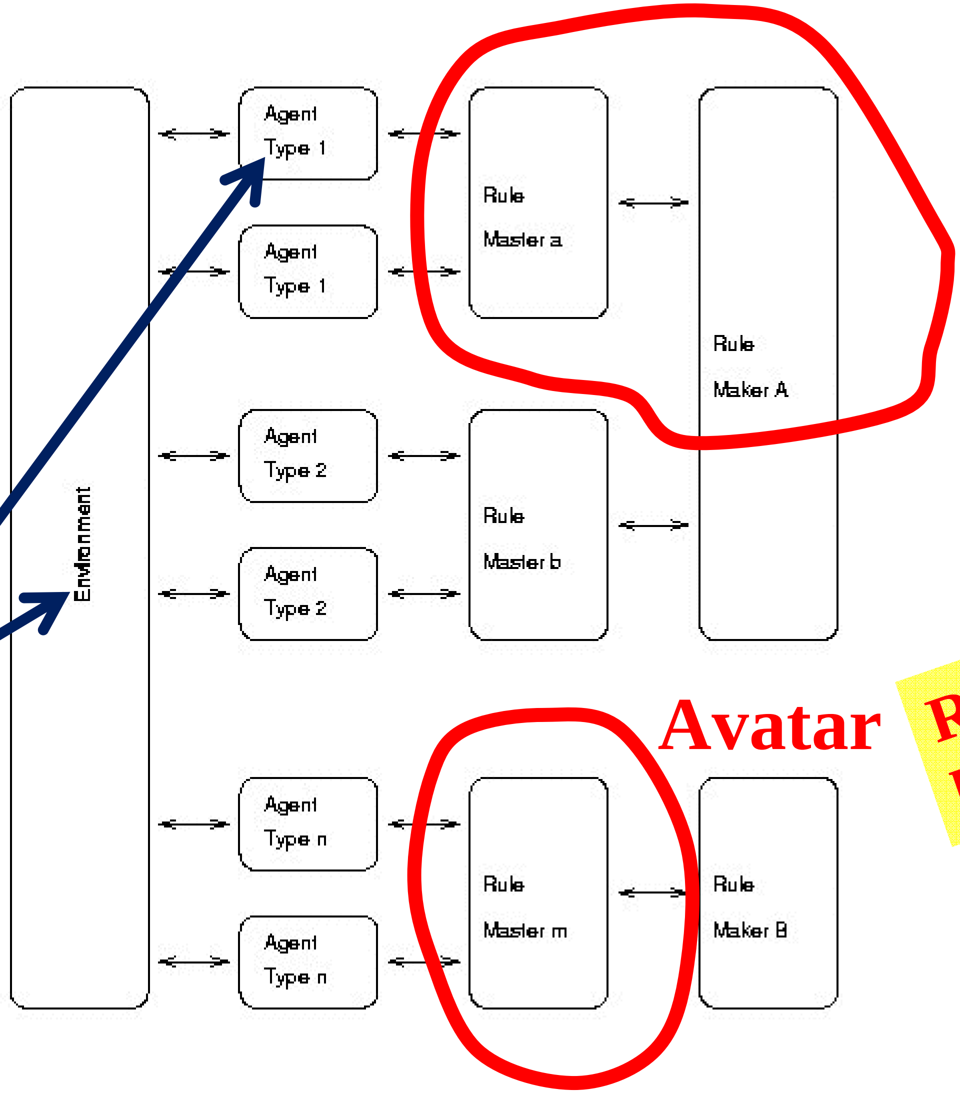


Swarm = a library of functions and a **protocol**



(A digression)

Environment, Agents and Rules representation, the ERA scheme



Fixed rules

NN

CS

GA

Reinforcement learning

Avatar

Microstructures, mainly related to time and parallelism

http://web.econ.unito.it/terna/ct-era/ct-era.html

Eating the pudding

The surprising world of the Chameleons, with SLAPP

From an idea of Marco Lamieri, a project work with Riccardo Taormina

http://eco83.econ.unito.it/terna/chameleons/chameleons.html

The metaphorical models we use here is that of the **changing color chameleons**

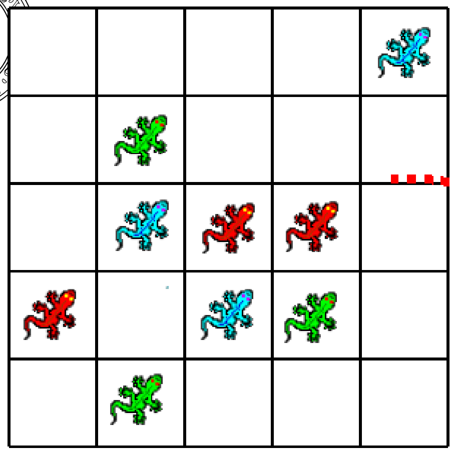
We have chameleons of three colors: red, green and blue

When two chameleons of different colors meet, they both change their color, assuming the third one (if all the chameleons get the same color, we have a steady state situation)

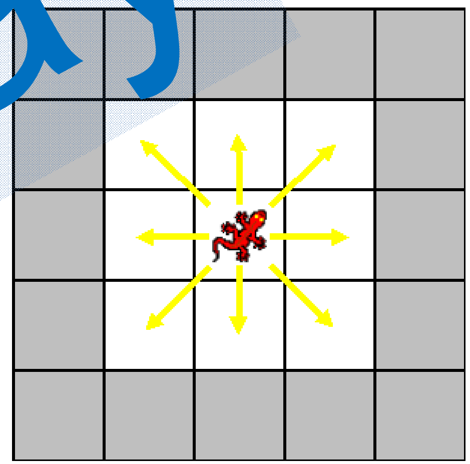
The metaphor can also be interpreted in the following way: an agent diffusing innovation or ideas (or political ideas) can change itself via the interaction with other agents: as an example think about an academic scholar working in a completely isolated context or interacting with other scholars or with entrepreneurs to apply the results of her work

The simple model moves agents and changes their colors, when necessary

But what if the chameleons of a given color want to preserve their identity?



0	0	0	0	1
0	1	0	0	0
0	1	0	0	0
0	0	1	1	0
0	1	0	0	0

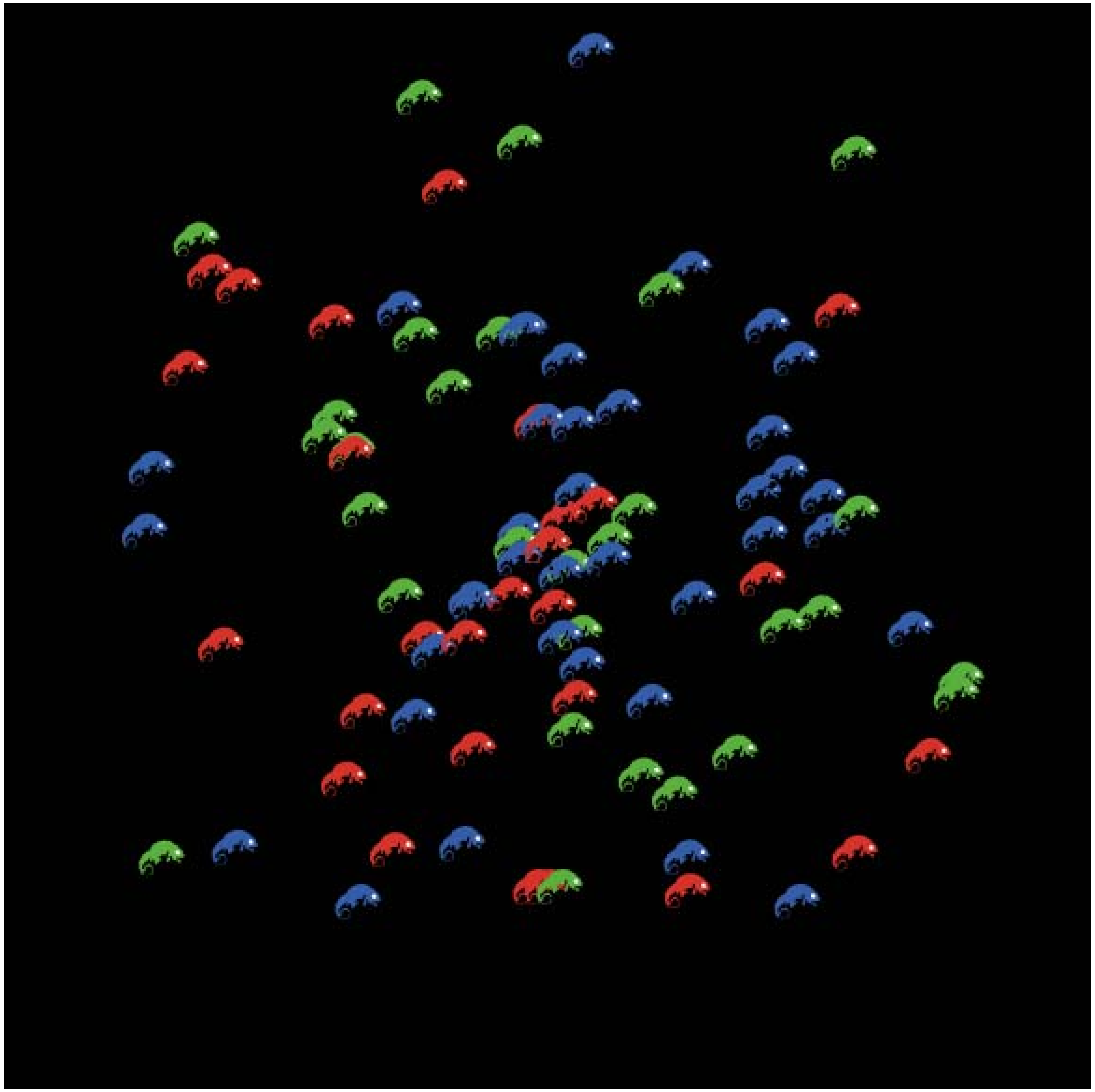


Let's play

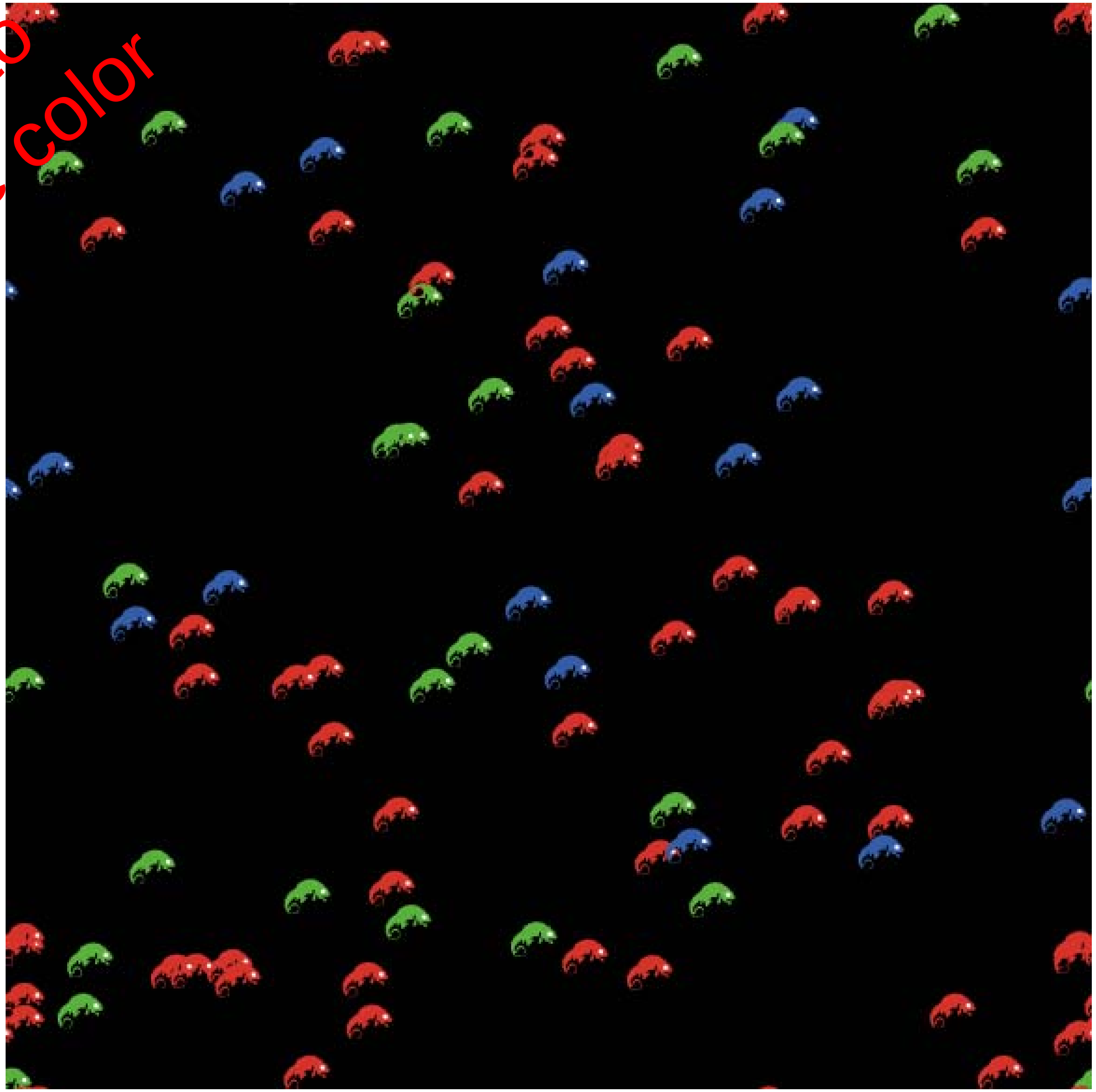
Preserving identity!

- **Reinforcement learning and pattern recognition, with bounded rationality**
- **Agent brain built upon 9 ANN**

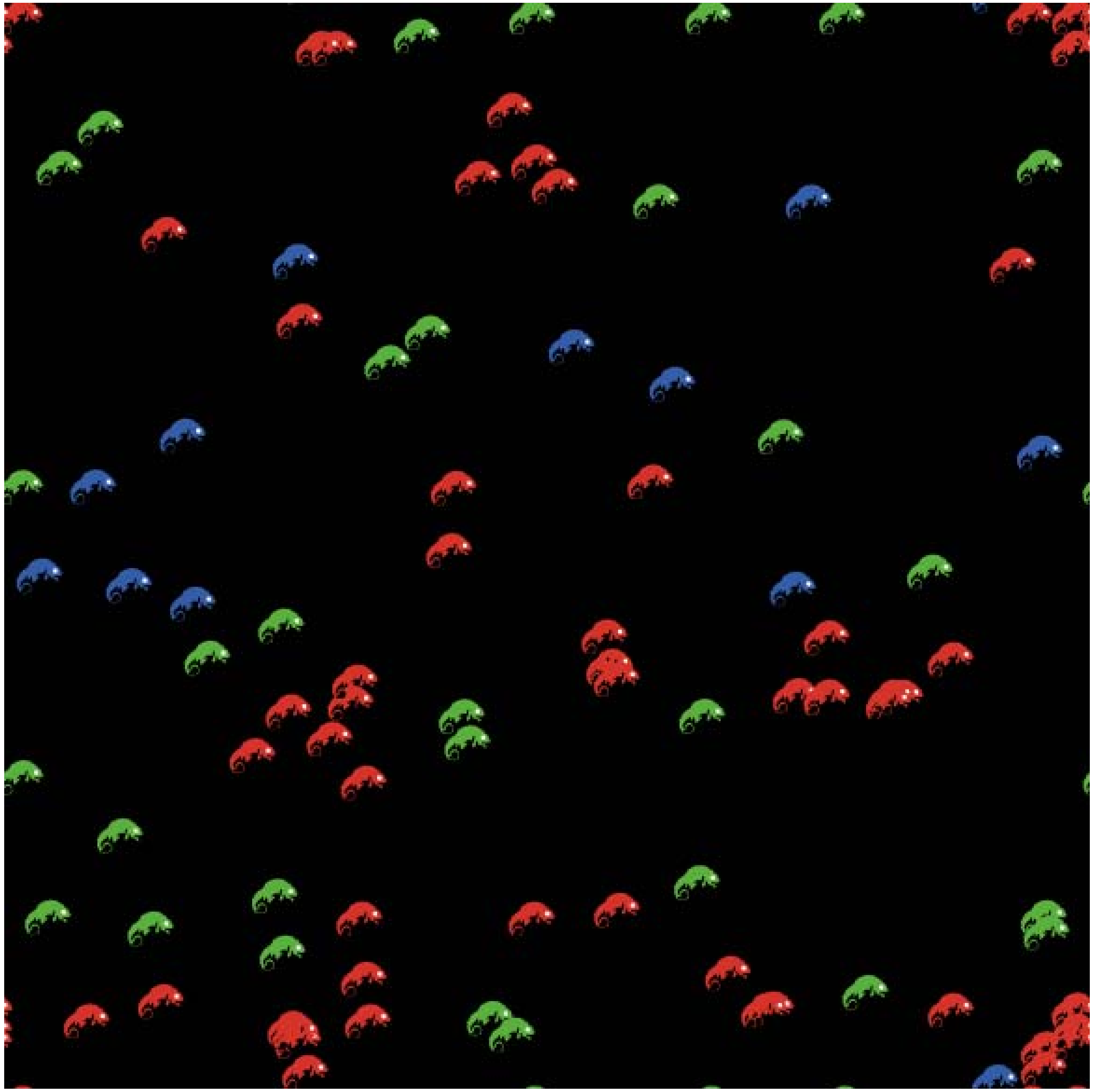
Random moves



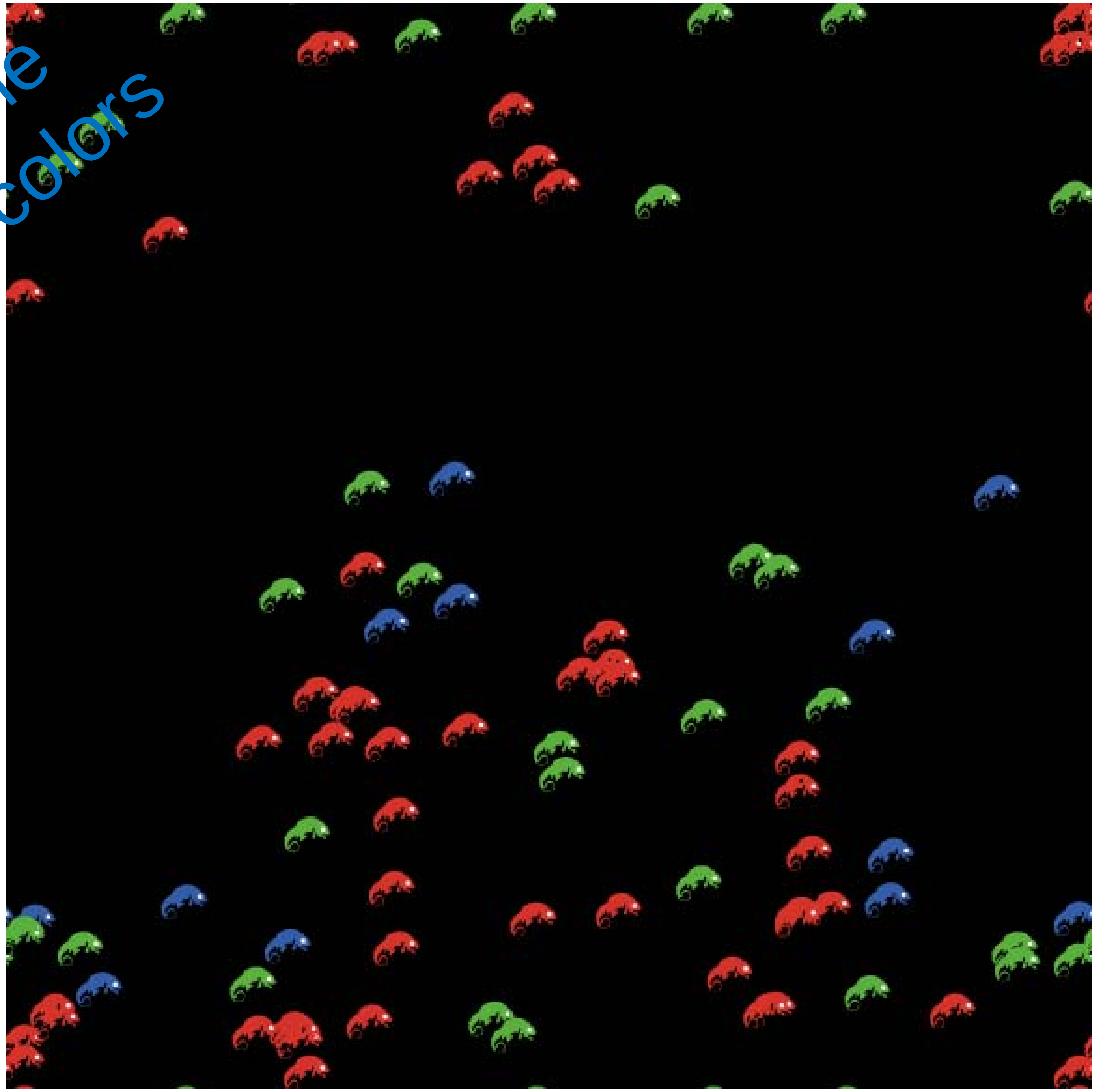
Red cham.
adverse to
change color

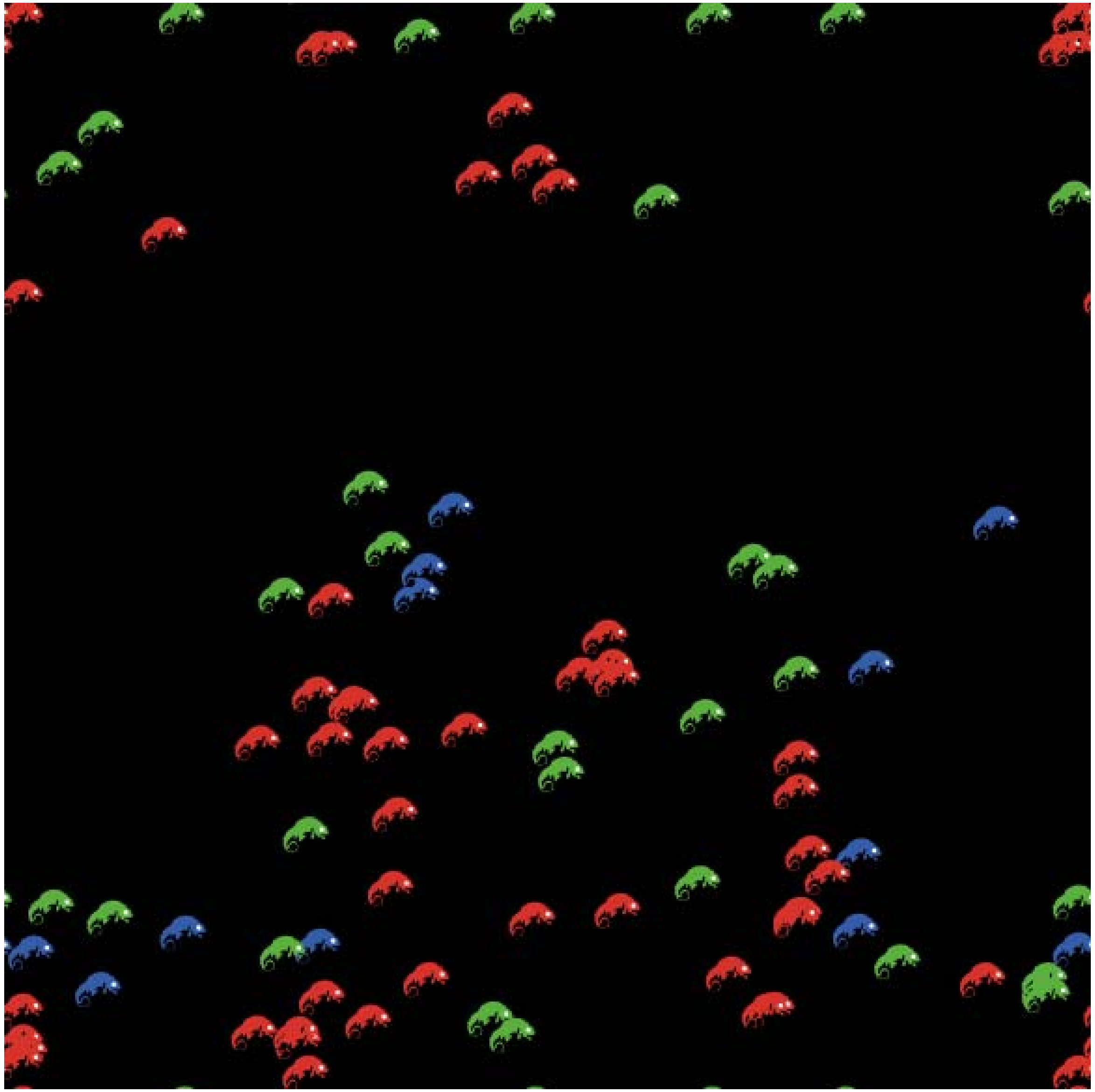


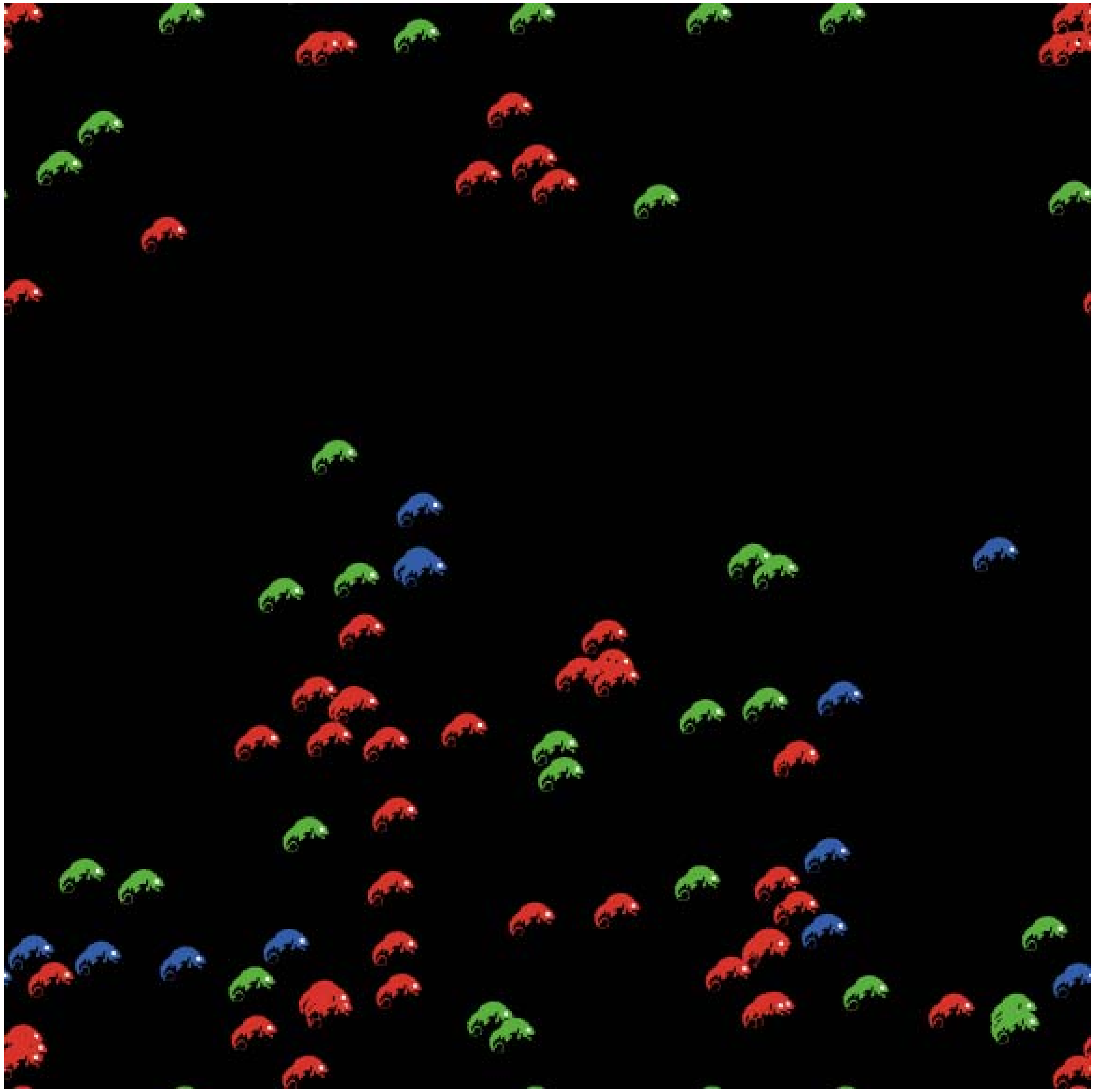
Green cham.
too

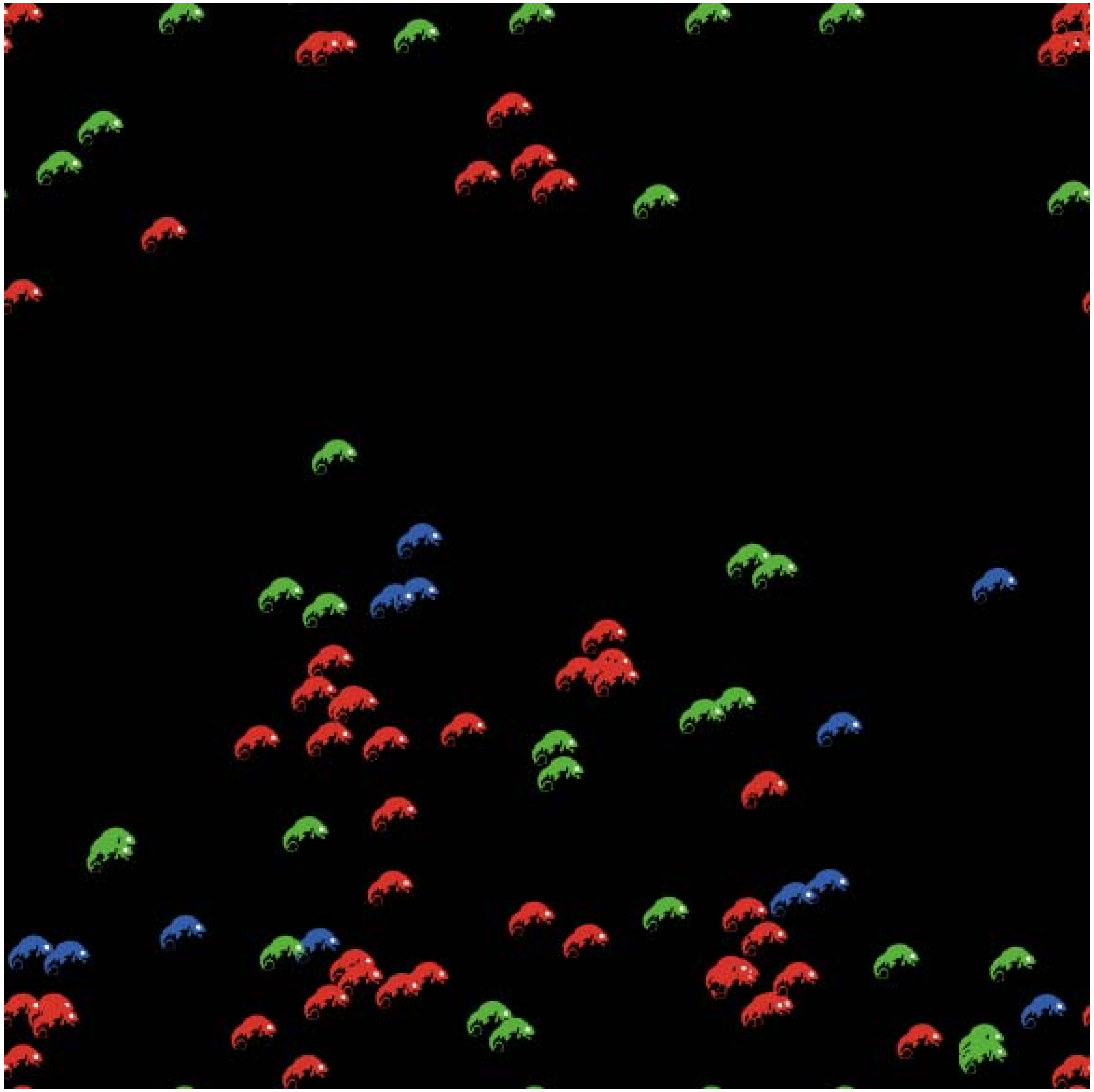


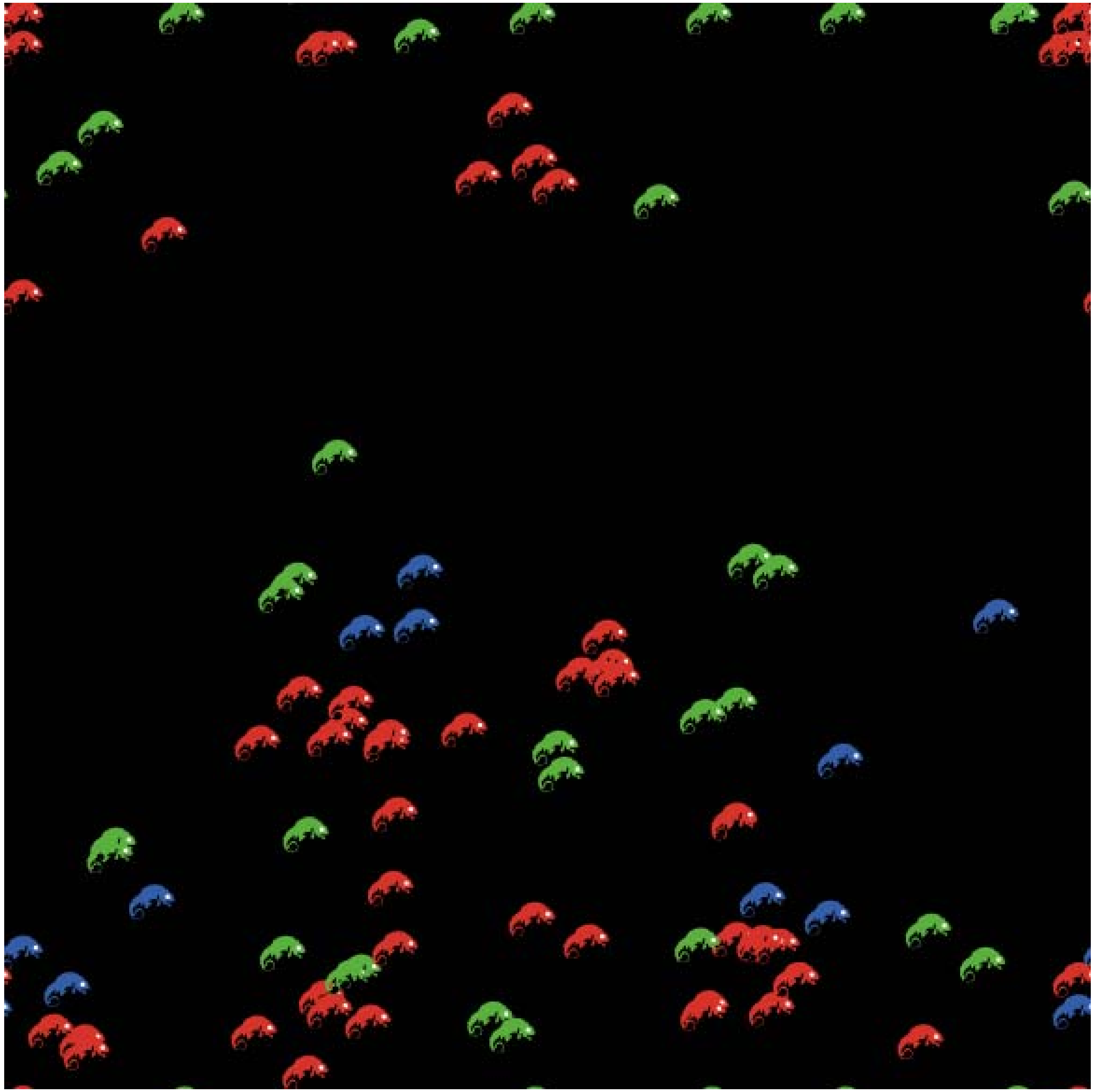
Blue cham. chase the other colors





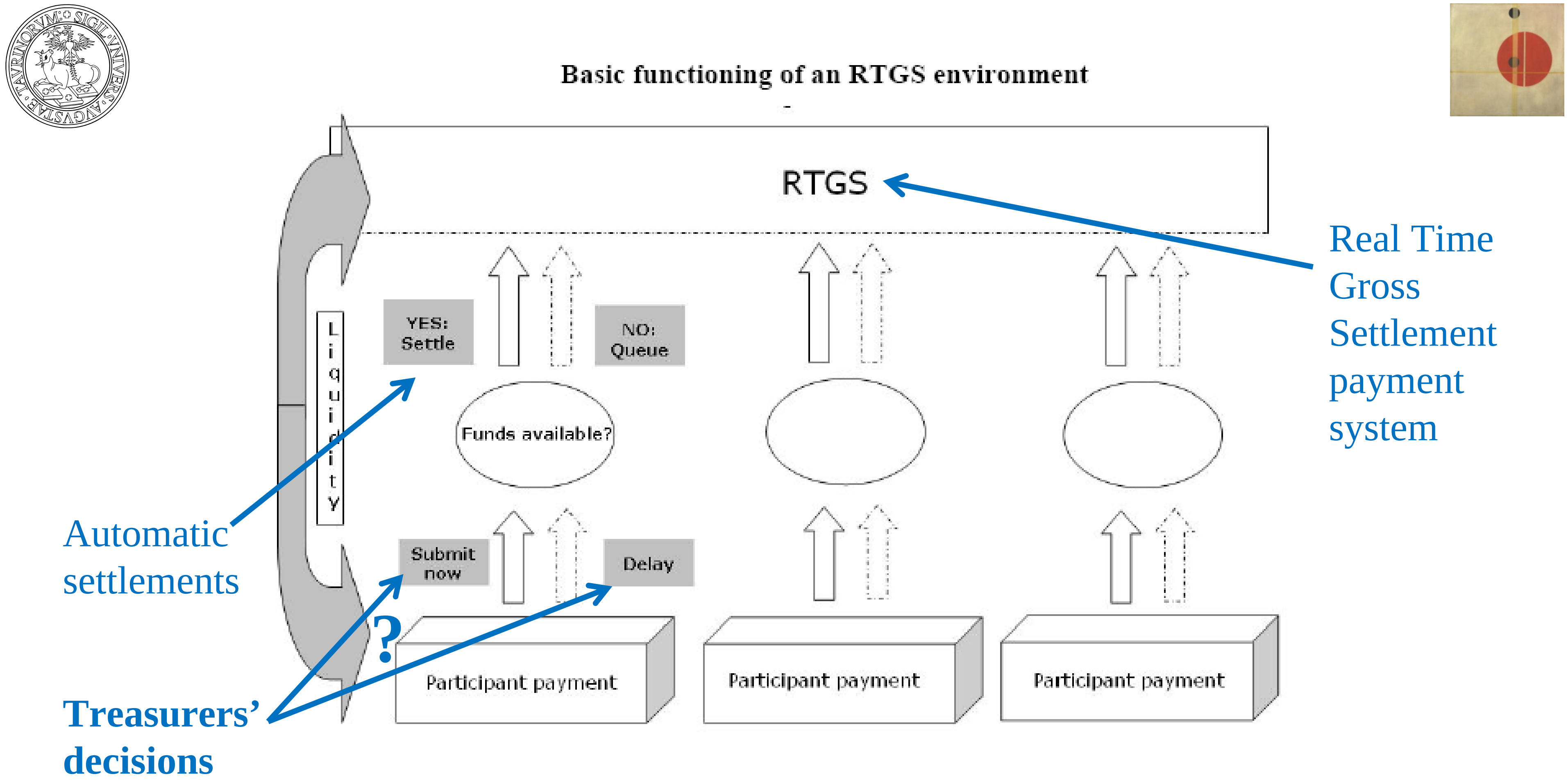






Eating the pudding again

SLAPP and the Italian Central Bank model of the internal interbank payment system



This figure, related to a StarLogo TNG implementation of the model, comes from: Luca Arciero+, Claudia Biancotti*, Leandro D'Aurizio*, Claudio Impenna+ (2008), An agent-based model for crisis simulation in payment systems, forthcoming.

+ Bank of Italy, Payment System Oversight Office; * Bank of Italy, Economic and Financial Statistics Department.

- Delays* in payments …
- … liquidity shortages …
- … in presence of unexpected negative operational or financial shocks …
- … financial crisis (generated or amplified by *), with domino effects

Two parallel highly connected institutions:

•RTGS (Real Time Gross Settlement payment system)

•eMID (electronic Market of Interbank Deposit)

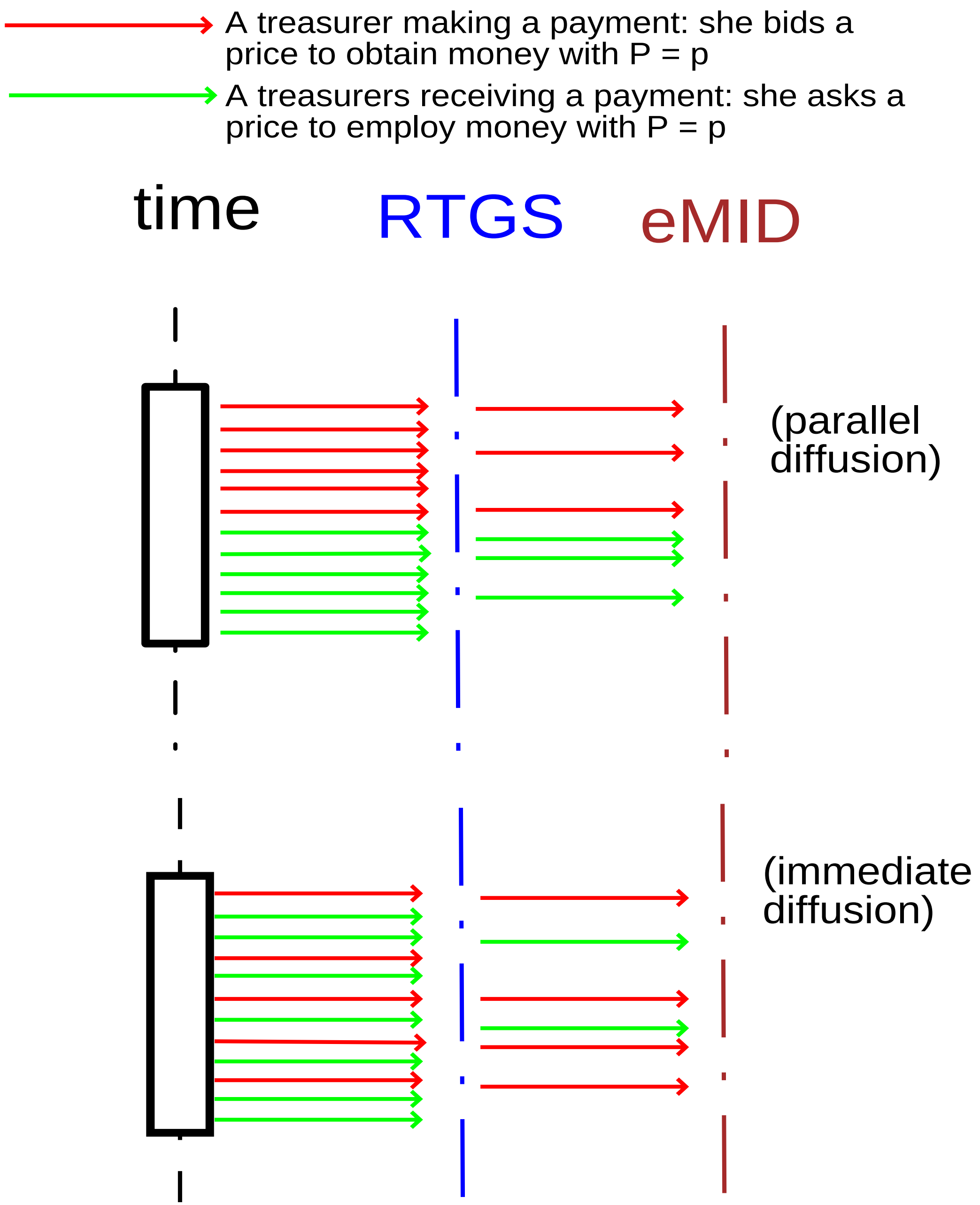
Starting from actual data, we simulate delays, looking at the emergent interest rate dynamics into the eMID

Agent based simulation as a magnifying glass to understand reality

SLAPP and the Italian Central Bank model:

a few complicated microstructures

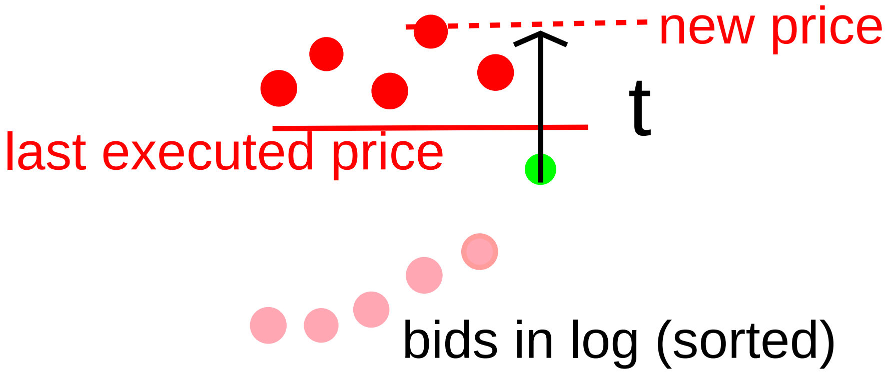
A "quasi UML" representation



NB prices are bid (or offered) by buyers and asked by sellers

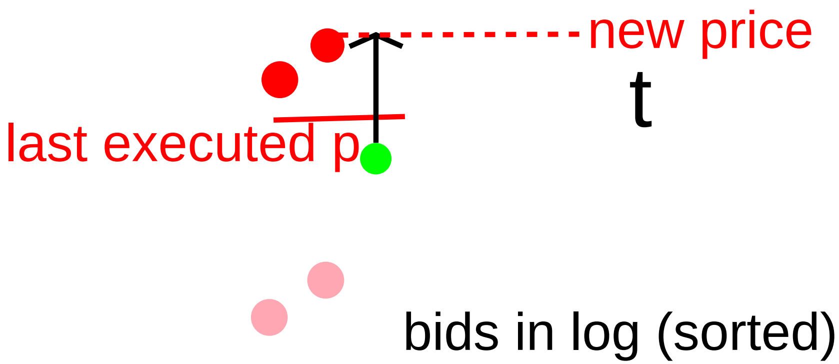
ask bid

parallel payment diffusion, looking at the last executed price



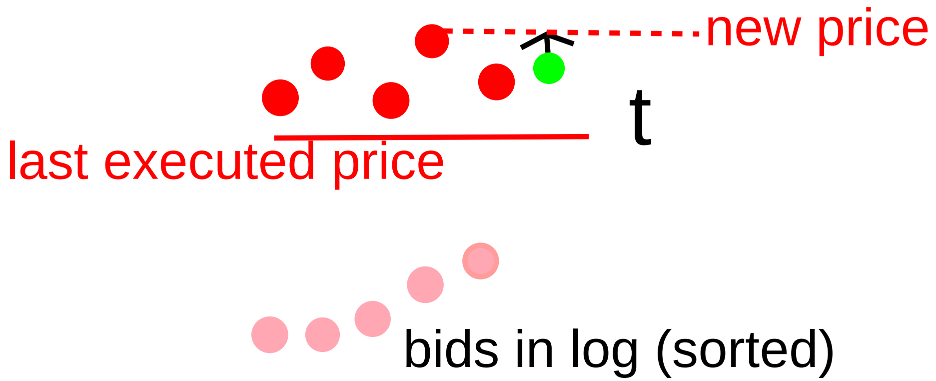
ask bid

immediate payment diffusion, looking at the last executed price



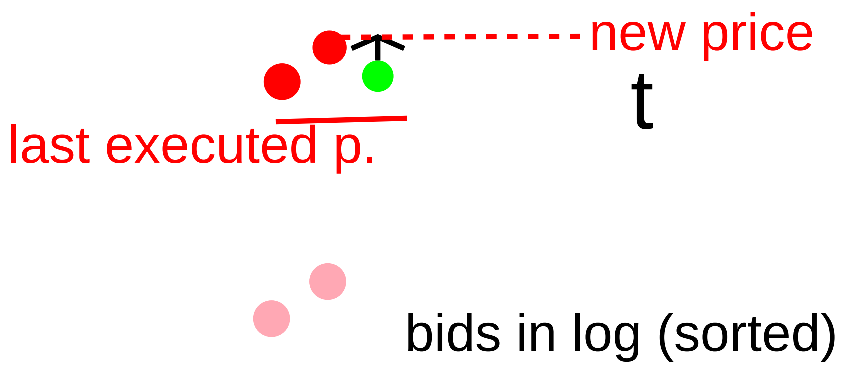
ask bid

parallel payment diffusion, looking at the best price in opposite log



ask bid

immediate payment diffusion, looking at the best price in opposite log



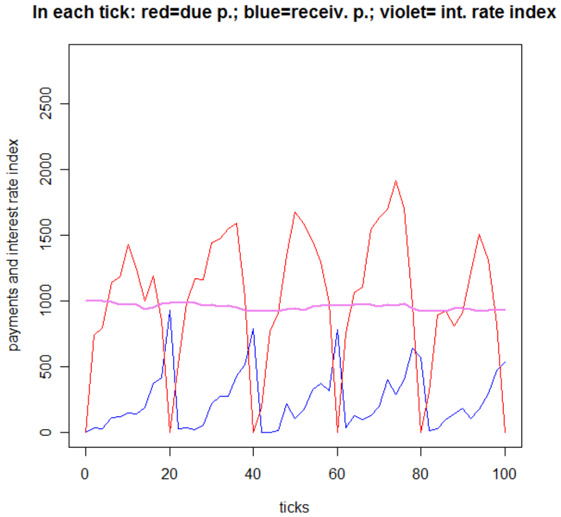
Microstructures: effects on interest rate dynamics

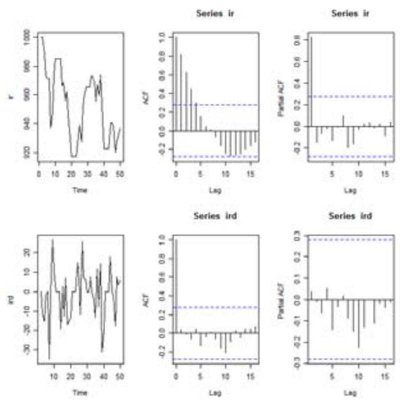
parallel / last

Model v.0.3.4

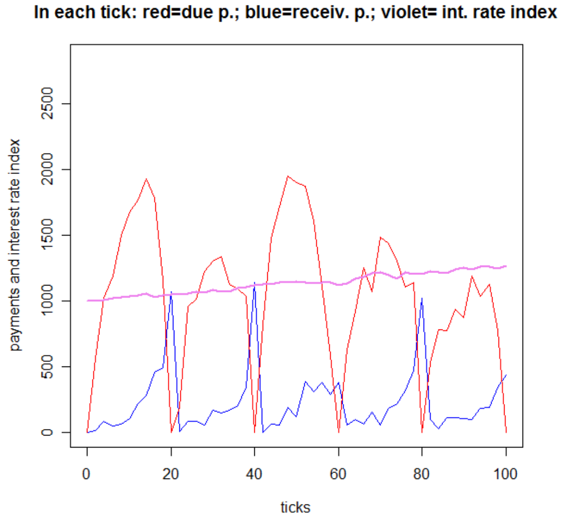
Used parameters: # of steps 100; payments per step max 30; # of banks 30; payment amount interval, max 30; time break at 20; observer interval 2; delay in payments, randomly set between 0 and max 18; bidding a price probability B; asking a price probability A

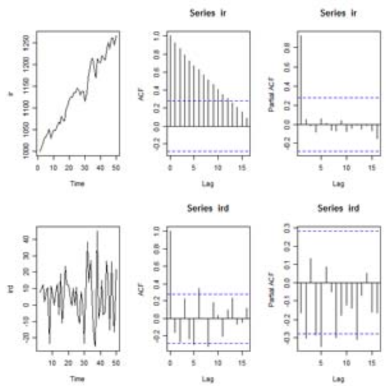
A 0.1 B 0.1



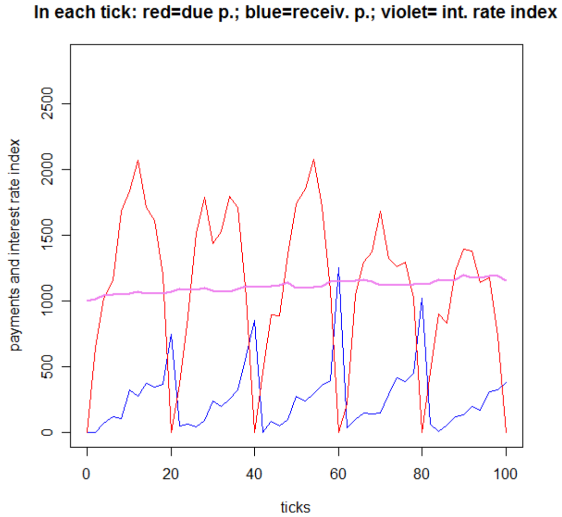


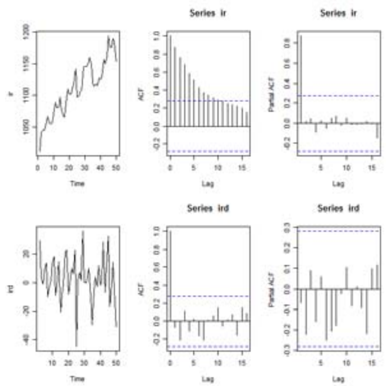
A 0.5 B 0.5





A 0.9 B 0.9





parallel / best

Model v.0.3.4

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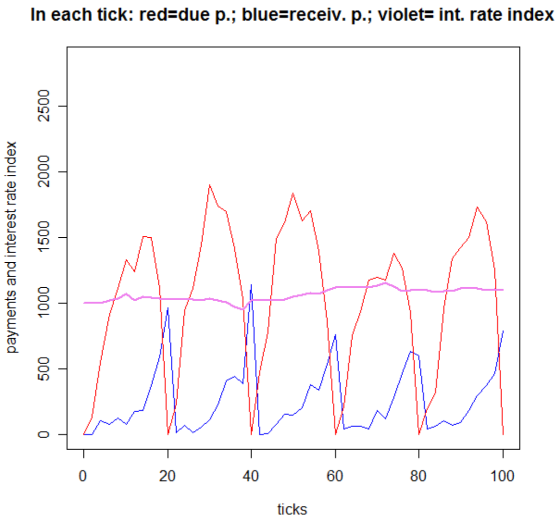
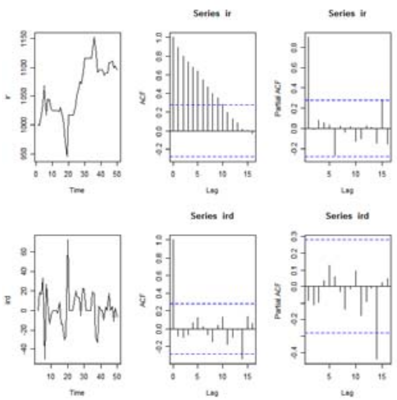
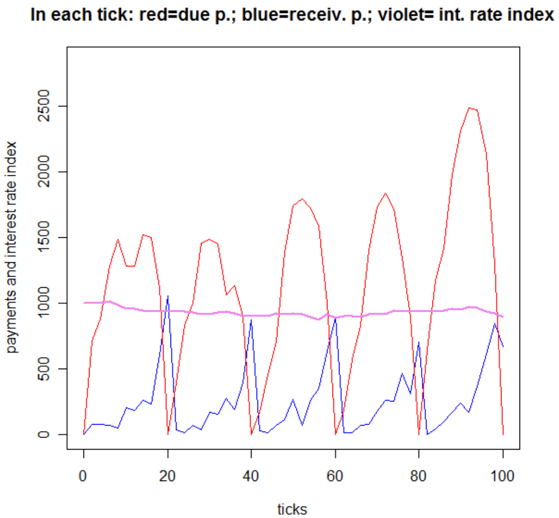
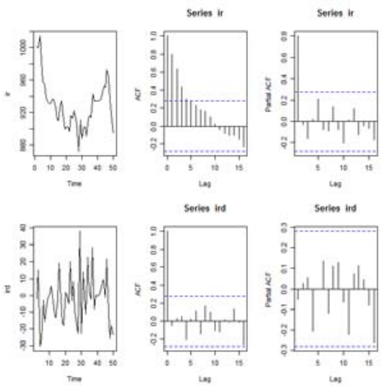


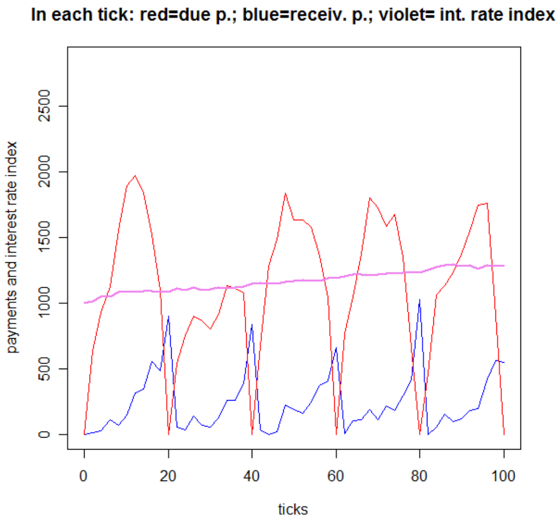


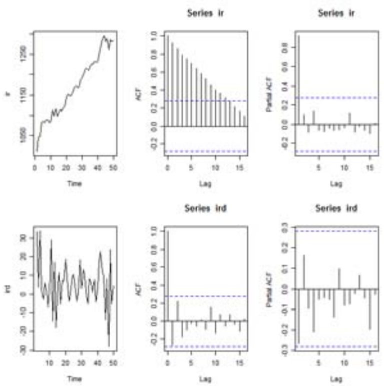
A 0.5 B 0.5





A 0.9 B 0.9



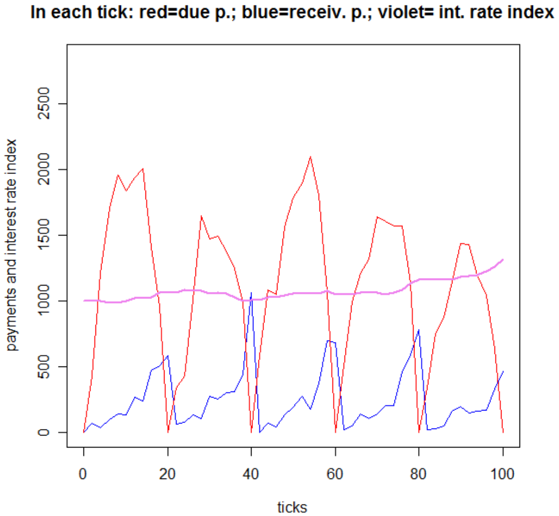


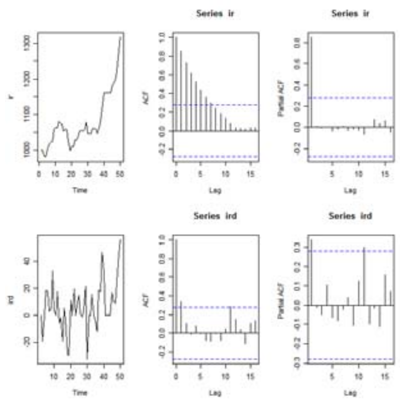
immediate / last

Model v.0.3.4

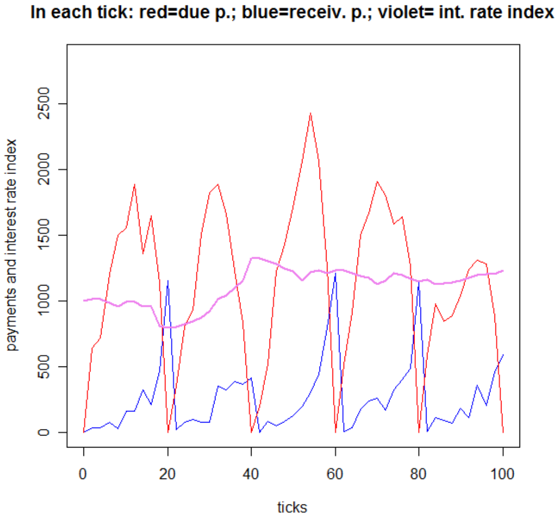
Used parameters: # of steps 100; payments per step max 30; # of banks 30; payment amount interval, max 30; time break at 20; observer interval 2; delay in payments, randomly set between 0 and max 18; bidding a price probability B; asking a price probability A

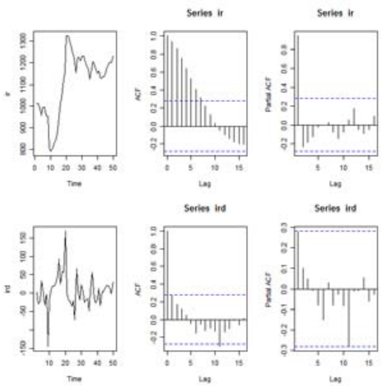
A 0.1 B 0.1



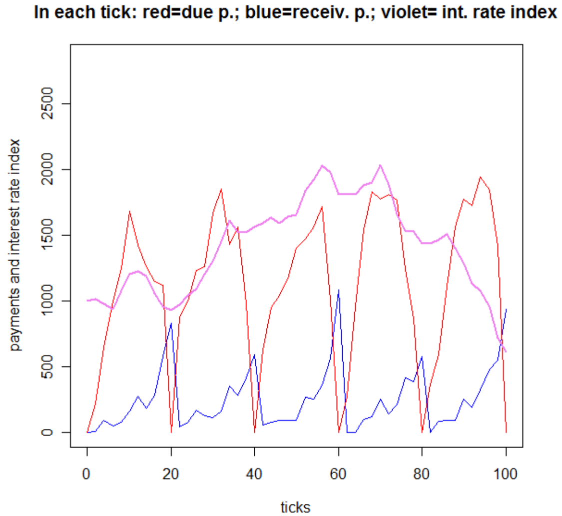


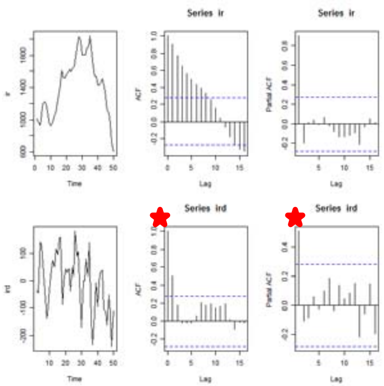
A 0.5 B 0.5





A 0.9 B 0.9



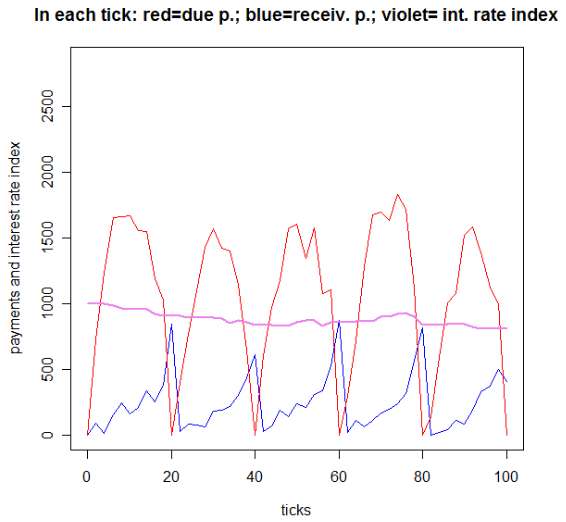


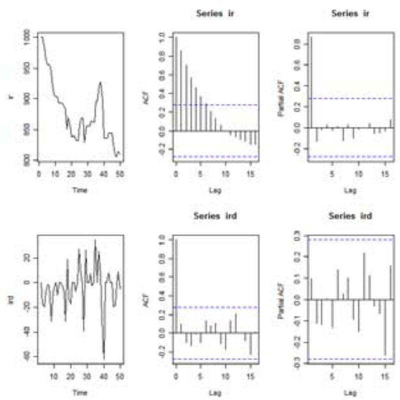
immediate / best

Model v.0.3.4

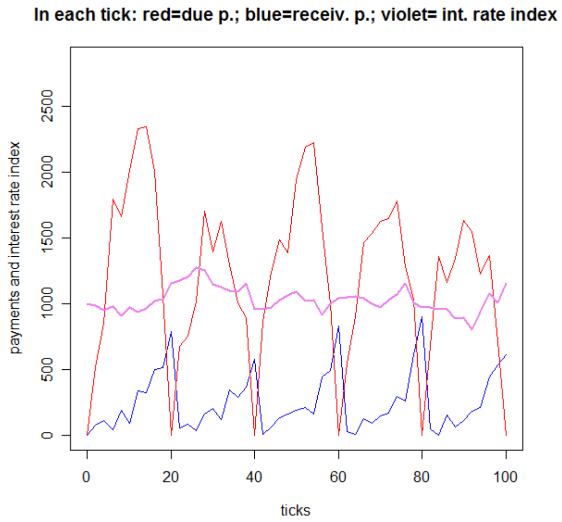
Used parameters: # of steps 100; payments per step max 30; # of banks 30; payment amount interval, max 30; time break at 20; observer interval 2; delay in payments, randomly set between 0 and max 18; bidding a price probability B; asking a price probability A

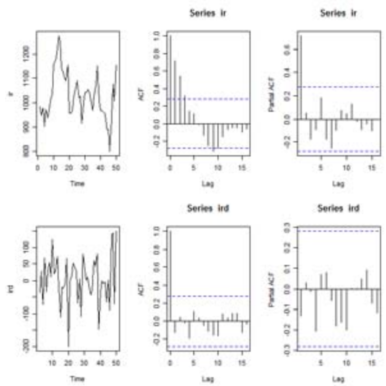
A 0.1 B 0.1



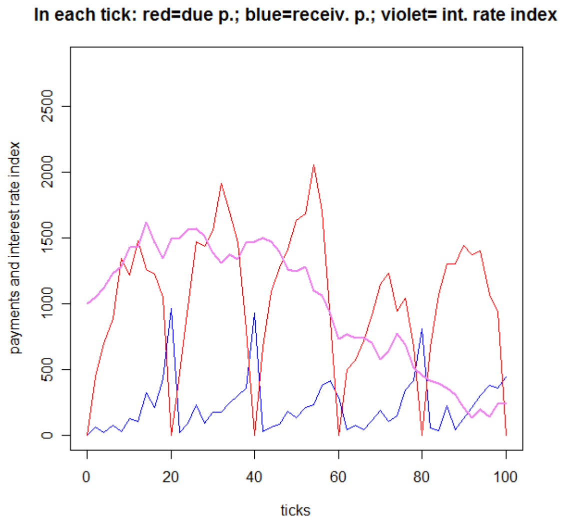


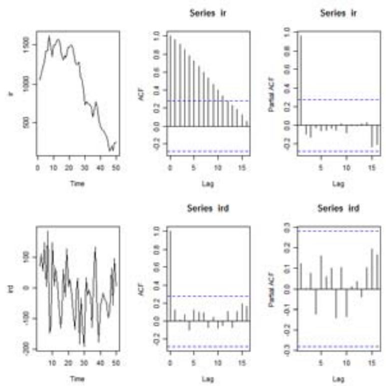
A 0.5 B 0.5





A 0.9 B 0.9

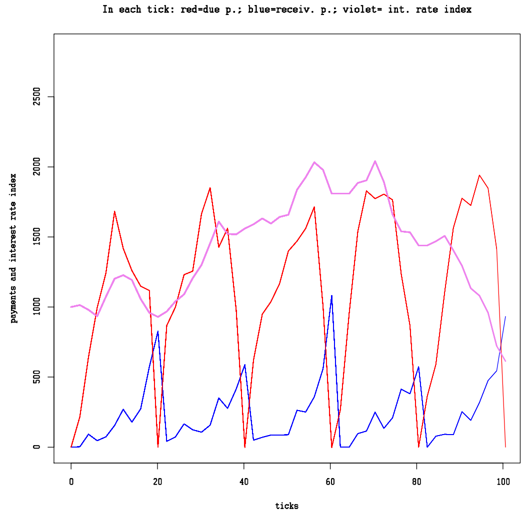


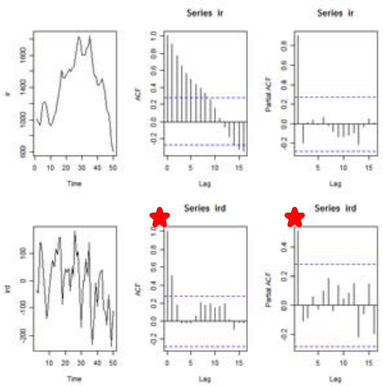


Look back at immediate / last

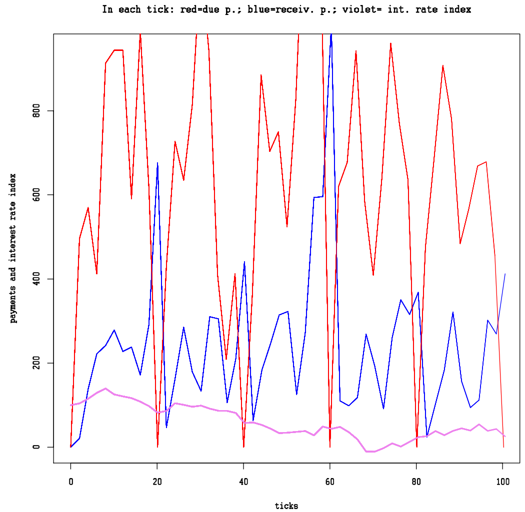
What if no delays in payments?

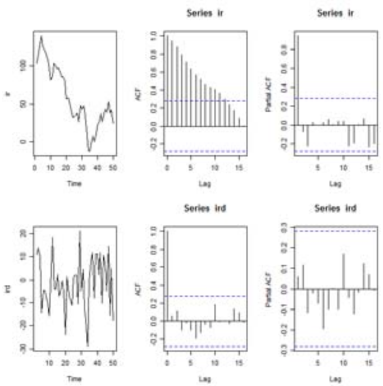
A 0.9 B 0.9 delay=18



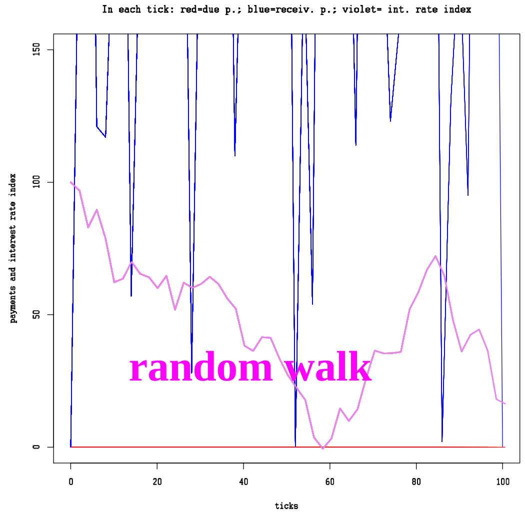


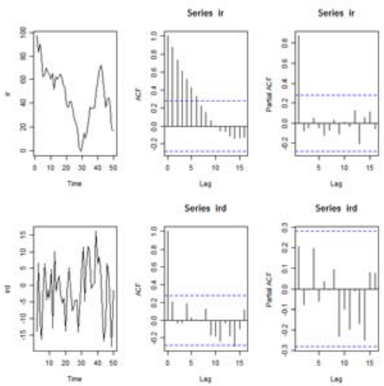
A 0.9 B 0.9 delay= 6





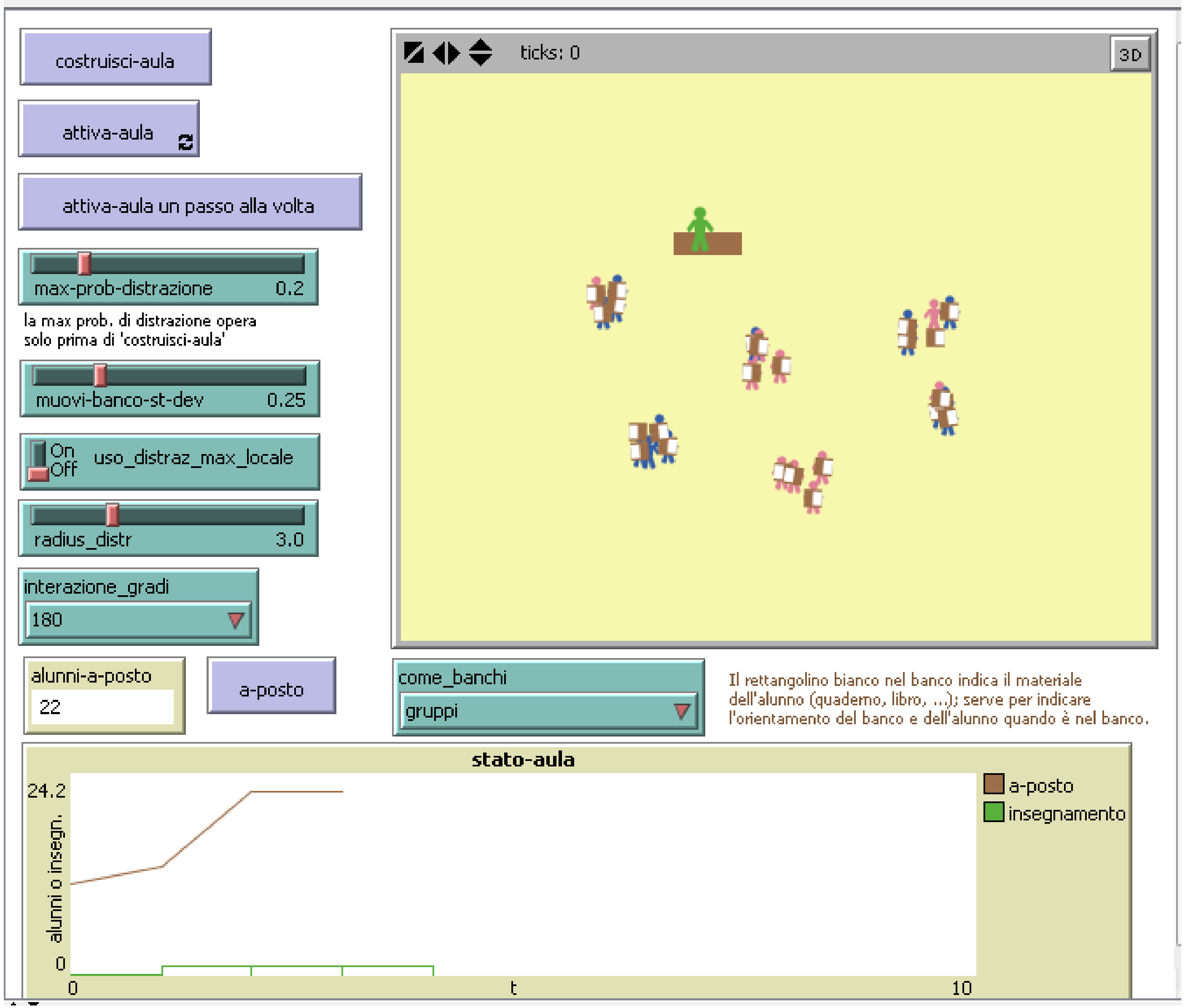
A 0.9 B 0.9 delay= 0





… the pudding …

Observations and agent based simulation in a primary school


costruisci-aula
attiva-aula
attiva-aula un passo alla volta
max-prob-distrazione 0.2
la max prob. di distrazione opera
solo prima di 'costruisci-aula'
muovi-banco-st-dev 0.25
On
Off
uso_distraz_max_locale
radius_distr 3.0
interazione_gradi
180
alunni-a-posto
22
a-posto
ticks: 0
3D
come_banchi
gruppi
Il rettangolino bianco nel banco indica il materiale
dell'alunno (quaderno, libro, ...); serve per indicare
l'orientamento del banco e dell'alunno quando è nel banco.
stato-aula
24.2
alunni o insegn.
0
0
t
10
a-posto
insegnamento

What if we want to characterize better our agent (with an ***Aesop fairy story on Artificial Neural Network***)

Repeated question: why a new tool and why SLAPP (Swarm-Like Agent Based Protocol in Python) as a preferred tool?

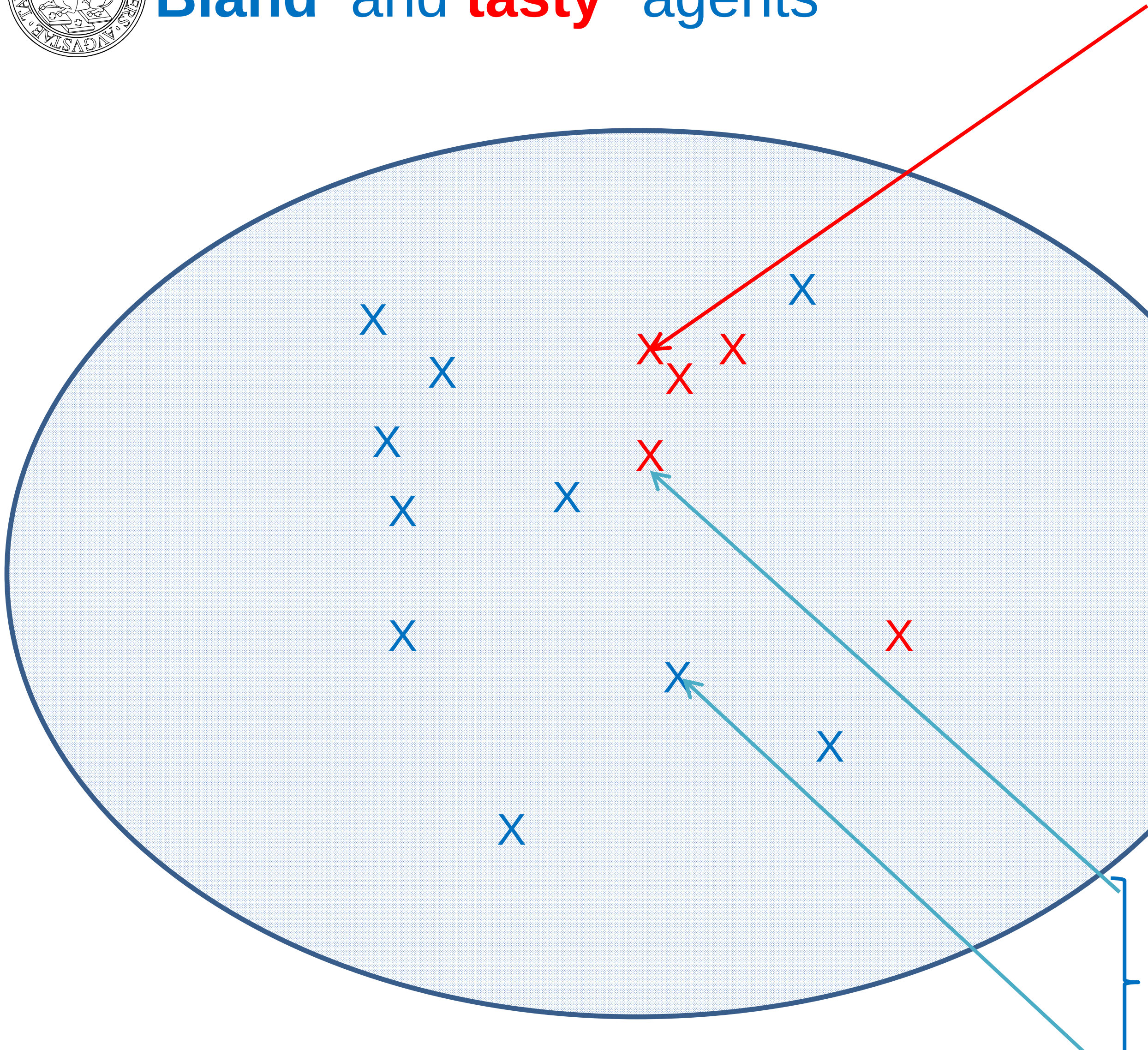
…

… to create the new AESOP (Agents and Emergencies for Simulating Organizations in Python) tool to model agents and their actions and interactions

Agents and schedule

Bland* and **tasty#** agents

Rules operating "in the foreground", explicitly managed via a script (with different sets of agents, with a different number of elements)



Rules operating "in the background" for all the agents, or only for the blue ones (to be decided)

**Bland = simple, unspecific, basic, insipid, …*
#Tasty = specialized, with given skills, discretionary, …

Empty schedule (no tasty agents, only bland ones, operating with the background rules)

	A	B	C	D	E
1	#	1			
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

```
How many 'bland' agents? 3
X Size of the world? 10
Y Size of the world? 10
How many cycles? (0 = exit) 5
World state number  0  has been created.
Agent number  0  has been created at  7 ,  1
Agent number  1  has been created at  3 ,  2
Agent number  2  has been created at  7 ,  0

Time = 1
agent #  0 moving
agent #  2 moving
agent #  1 moving
Time =  1 ask all agents to report position
Agent number  0  moved to X =  0.013103229603 5  Y =  3.0131032296
Agent number  1  moved to X =  8.9868967704  Y =  0.0
Agent number  2  moved to X =  0.986896770397  Y =  3.9868967704
Time = 2
agent #  0 moving
agent #  1 moving
agent #  2 moving
Time =  2 ask first agent to report position
Agent number  0  moved to X =  6.18205342701  Y =  6.844153032 2
```

Creation of the bland agents

bland agents **acting with the background rules**

All the agents reporting their position **(background operation)**

The agent # 0 reporting … **(b. op.)**

Schedule driving bland agents (no tasty agents)

Agent -> all agents; Agent0 -> bland agents; in this case the two sets are coincident

1	#		1			standard (internal) actions, like move, are applied to all agents
2	Agent0	eat				0 means internal agents
3	Agent0	dance				
4	#		2			
5	#		4			
6	Agent		0.5	dance		Agent without speficitation means all
7	Agent3	eat				3 means agents of type 3
8	WorldState		0.5	setGeneralMovingProb		
9	#		5			comments here or in successive columns
10	Agent	eat				
11	Agent	dance				
12	#		30			
13	Agent1	dance				1 means agents of type 1
14	#		31			
15	Agent1		0.5	dance		
16						

Empty sets, in this case

Acting on bland (blue) agents and on tasty (red) ones

```
How many 'bland' agents? 3
X Size of the world? 10
Y Size of the world? 10
How many cycles? (0 = exit) 5
World state number  0  has been created.
Agent number  0  has been created at  7 ,  1
Agent number  1  has been created at  3 ,  2
Agent number  2  has been created at  7 ,  0

Time = 1
agent #  1 moving
agent #  2 moving
agent #  0 moving
I'm agent  1:  nothing to eat here!
I'm agent  2:  nothing to eat here!
I'm agent  0:  nothing to eat here!
I'm agent  0:  it's not time to dance!
I'm agent  1:  it's not time to dance!
I'm agent  2:  it's not time to dance!
Time =  1 ask all agents to report position
Agent number  0  moved to X =  0.972690201302  Y =  7.0273097987
Agent number  1  moved to X =  6.9726902013  Y =  2.0
Agent number  2  moved to X =  7.0  Y =  6.0273097987
```

bland agents

Schedule driving bland agents (with tasty agents)

Agent -> all agents; Agent0 -> background agents

1	#		1			standard (internal) actions, like move, are applied to all agents
2	Agent0	eat				0 means internal agents
3	Agent0	dance				
4	#		2			
5	#		4			
6	Agent		0.5	dance		Agent without speficitation means all
7	Agent3	eat				3 means agents of type 3
8	WorldState		0.5	setGeneralMovingProb		
9	#		5			comments here or in successive columns
10	Agent	eat				
11	Agent	dance				
12	#		30			
13	Agent1	dance				1 means agents of type 1
14	#		31			
15	Agent1		0.5	dance		
16						

Non empty sets, in this case

Effects on bland (blue) agents and tasty (red) ones

Set of agents (any kind of names)

agType1.txt

111	…	…
222	…	…

IDs

Specific attributes of each agent

agType3.txt

1111

```
How many 'bland' agents? 3
X Size of the world? 3
Y Size of the world? 3
How many cycles? (0 = exit) 32
World state number  0  has been created.
Agent number  0  has been created at  0 ,  2
Agent number  1  has been created at  1 ,  0
Agent number  2  has been created at  0 ,  2

creating agType1 # 111
Agent number  111  has been created at  1 ,  1
creating agType1 # 222
Agent number  222  has been created at  2 ,  0

creating agType3 # 1111
Agent number  1111  has been created at  2 ,  2

Time = 1
agent #  2 moving
agent # 222 moving
agent #  0 moving
agent # 111 moving
agent #  1 moving
agent # 1111 moving
```

tasty agents

bland and tasty agents

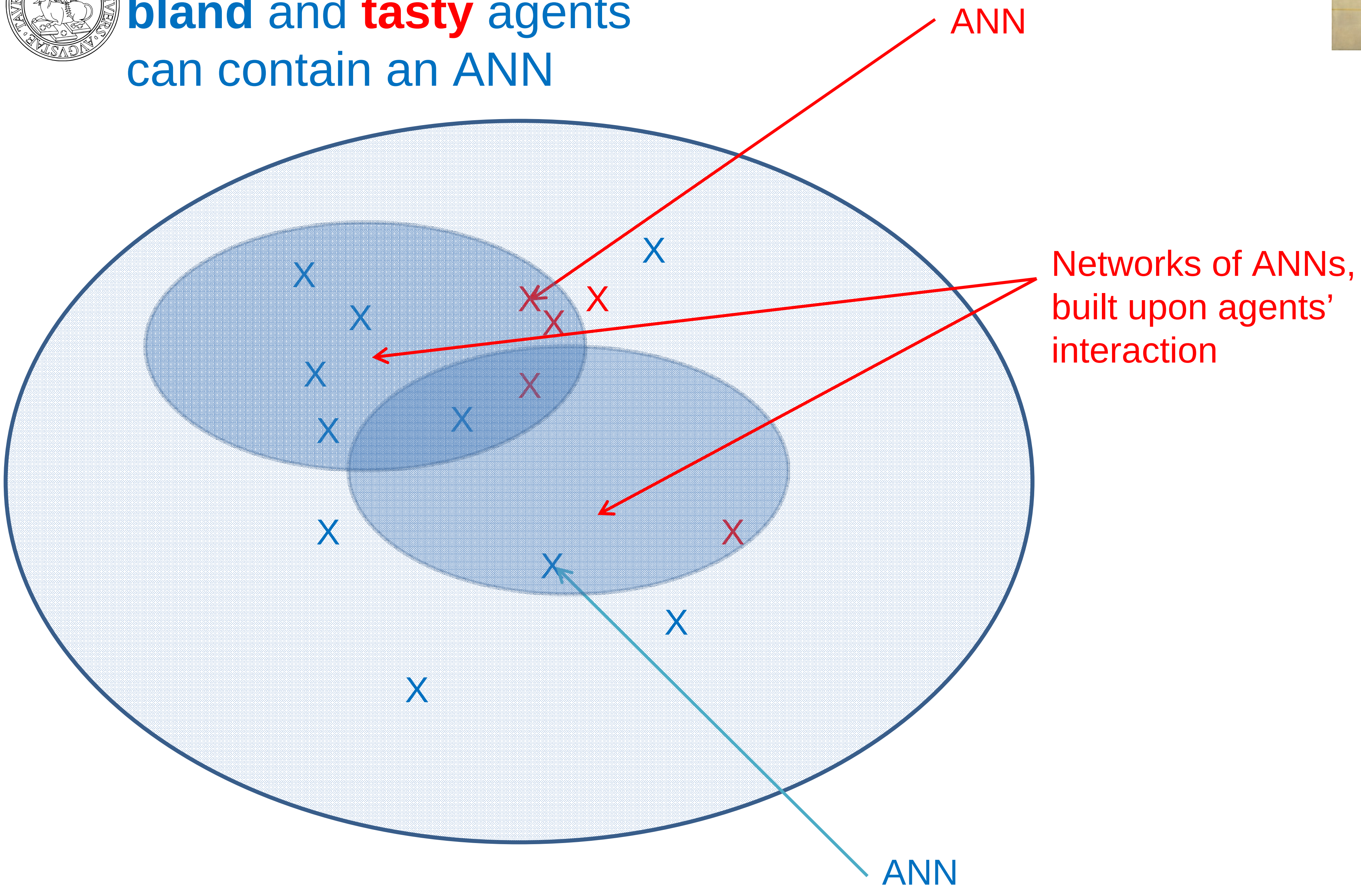
```
Time = 5
agent # 222 moving
agent #   1 moving
I'm agent 1111:  nothing to eat here!
I'm agent   2:  nothing to eat here!
I'm agent 111:  nothing to eat here!
I'm agent   0:  nothing to eat here!
I'm agent 222:  nothing to eat here!
I'm agent   1:  nothing to eat here!
I'm agent   0:  it's not time to dance!
I'm agent 222:  it's not time to dance!
I'm agent 1111:  it's not time to dance!
I'm agent   2:  it's not time to dance!
I'm agent 111:  it's not time to dance!
I'm agent   1:  it's not time to dance!


Time =31
agent #   1 moving
agent # 111 moving
agent #   0 moving
agent #   2 moving
I'm agent 222:  it's not time to dance!
Time =  31 ask all agents to report position
```

#	31	
Agent1	0.5	dance

Artificial neural networks into the agents

bland and **tasty** agents can contain an ANN



$$y = g(x) = f(B\, f(A\, x))$$

(m) (n)

actions information

or

$$y_1 = g_1(x) = f(B_1\; f(A_1\, x))$$

(1) (n)

…

$$y_m = g_m(x) = f(B_m\, f(A_m\, x))$$

(1) (n)

a - Static ex-ante learning (on examples)

Rule master

X_a Y_a
---------------------- --
$X_{a,1}$ $Y_{a,1}$
… …
$X_{a,m-1}$ Y_{a,m_a-1}
$X_{a,m}$ Y_{a,m_a}

X_b Y_b
---------------------- --
$X_{b,1}$ $Y_{b,1}$
… …
$X_{b,m-1}$ Y_{b,m_b-1}
$X_{b,m}$ Y_{b,m_b}

Different agents, with different set of examples, estimating and using different sets A and B of parameters

b - Continuous learning (trials and errors)

$$z = g([x,y]) = f(B\ f(A\ [x,y]))$$

(p)

(n+m)

actions

Rule master

effects

information

Coming from simulation

the agents will choose Z maximizing:
(i)individual U, with norms
(ii)societal wellbeing

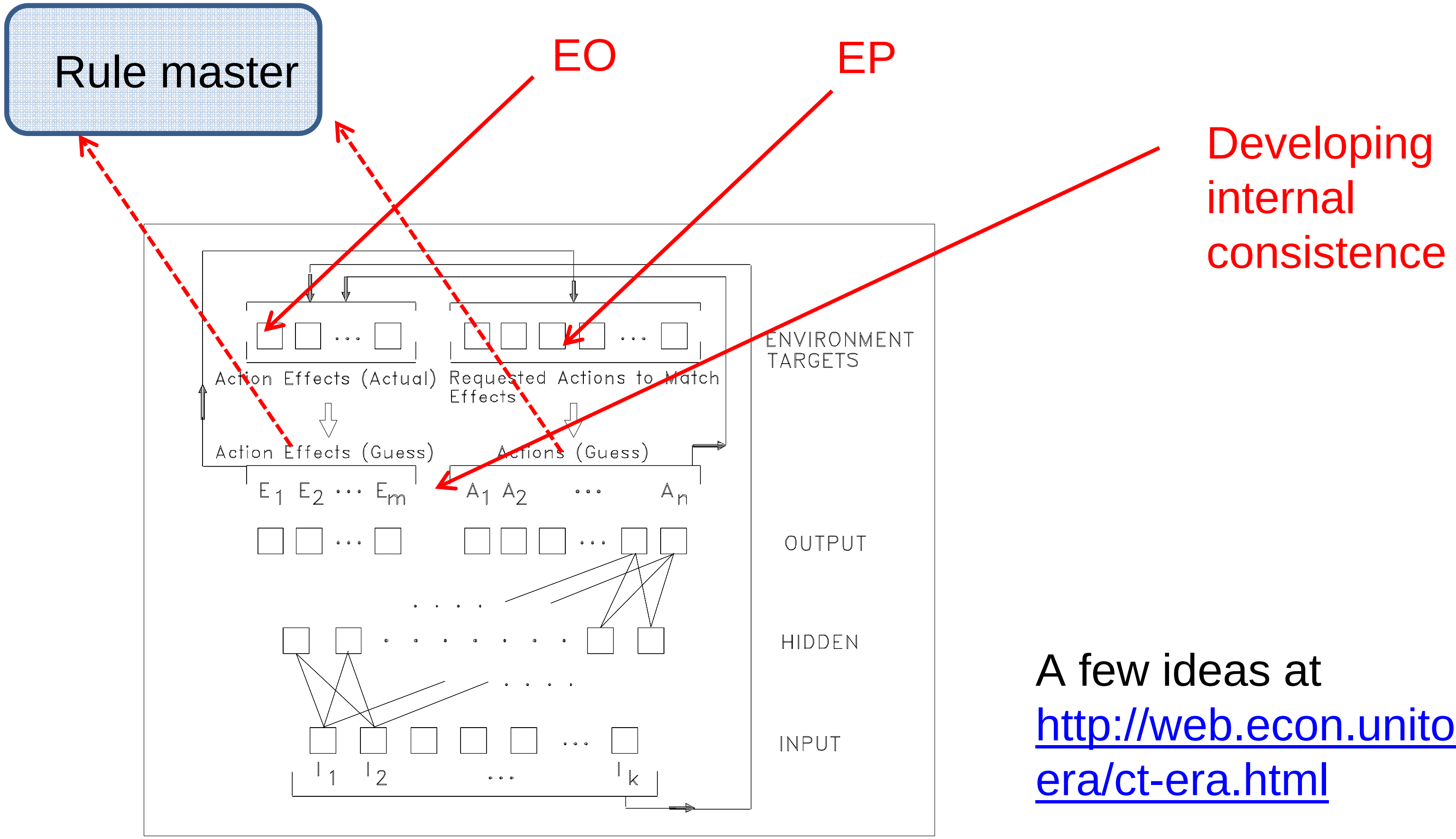
accounting for laws

at t=0 or at given t=k steps, all or a few agents act randomly

Different agent, estimating and using different set A and B of parameters (or using the same set of parameters)

Emergence of norms **[modifying f(u) , as new norms do, or the set z, as new laws do]**

c - Continuous learning (cross-targets)



A few ideas at http://web.econ.unito.it/terna/ct-era/ct-era.html

Thanks for your attention

terna@econ.unito.it
http://web.econ.unito.it/terna

SLAPP & Aesop are at
http://eco83.econ.unito.it/terna/slapp