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Applying Agent Based Simulation to a Huge Actual Problem: the Interbank Payment System

ESSA Summer School, 18 - 22 July, 2011, University of Surrey

How to start a huge simulation project

How to start a huge simulation project

vs.

your boss, your supervisor,

yourself

Build a (tiny) proof of concept

For the the actual problem of delays and lacking liquidity in interbank payments, the starting point has been a “visual” description and implementation:

http://jasss.soc.surrey.ac.uk/12/1/2.html

Luca Arciero, Claudia Biancotti, Leandro D'Aurizio and Claudio Impenna (2009)

Exploring Agent-Based Methods for the Analysis of Payment Systems: A Crisis Model for StarLogo TNG

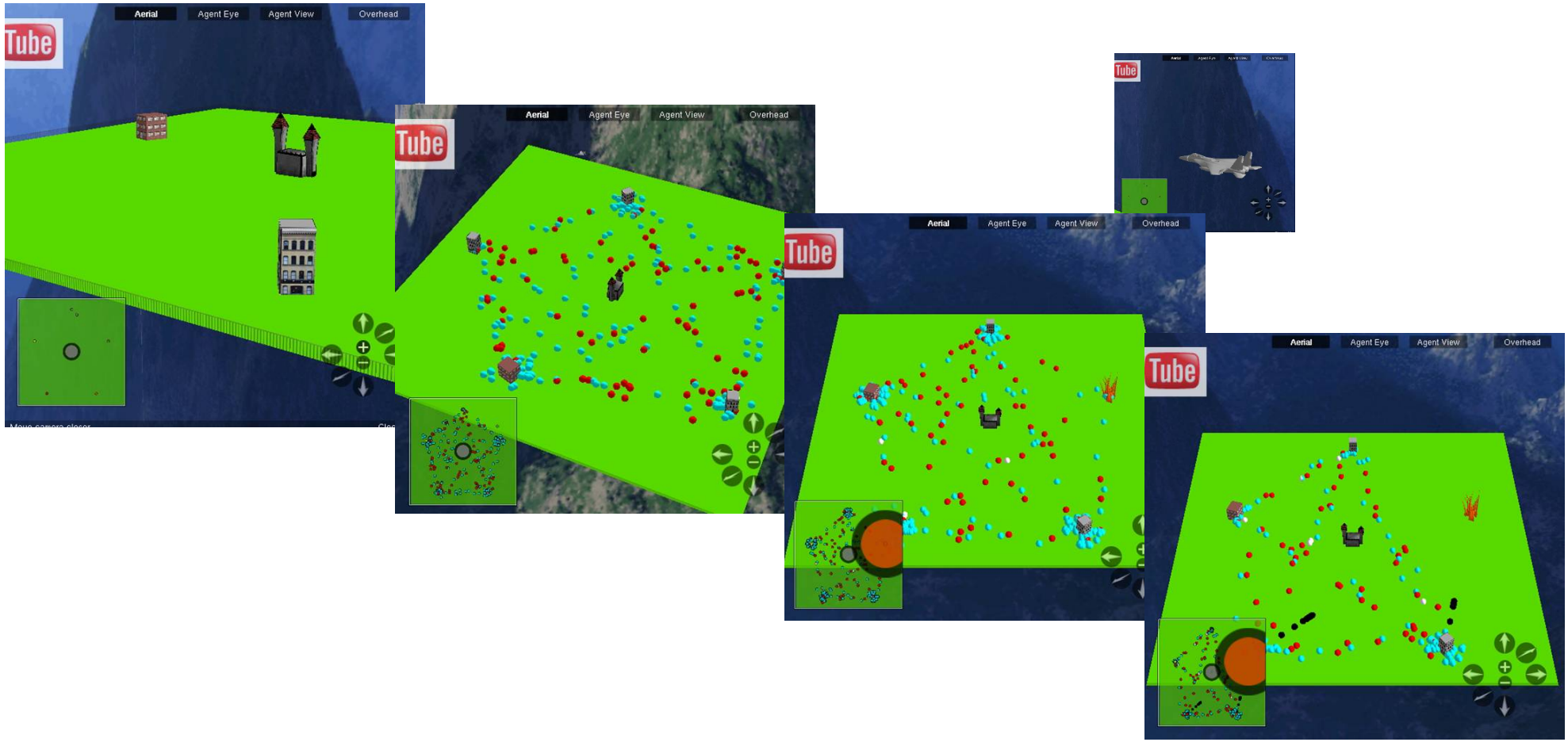
The paper presents an exploratory agent-based model of a real time gross settlement (RTGS) payment system.

Banks are represented as agents who exchange payment requests, which are then settled according to a set of simple rules. The model features the main elements of a real-life system, including a central bank acting as liquidity provider, and a simplified money market.

A simulation exercise using synthetic data of the Italian RTGS predicts the macroscopic impact of a disruptive event on the flow of interbank payments.

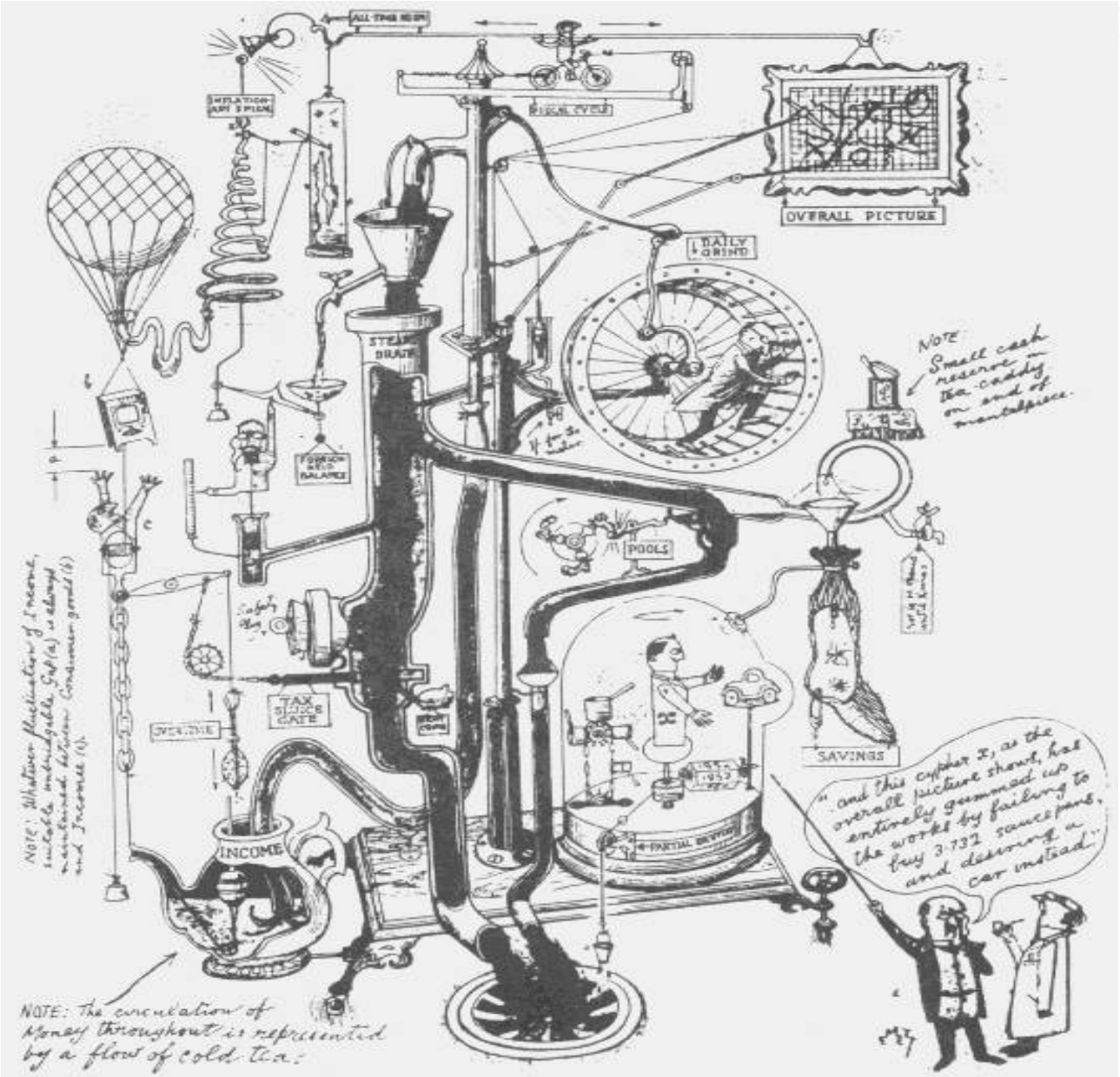
The simulated world is depicted one second before (left) and 140 seconds after (right) a critical event hitting the circled agent.

Have a look to a movie reproducing the simulation



Moving to a realistic scale model

Our goal: understanding and controlling a tiny part of the economic complexity in action



MACHINE DESIGNED TO SHOW THE WORKING OF THE ECONOMIC SYSTEM

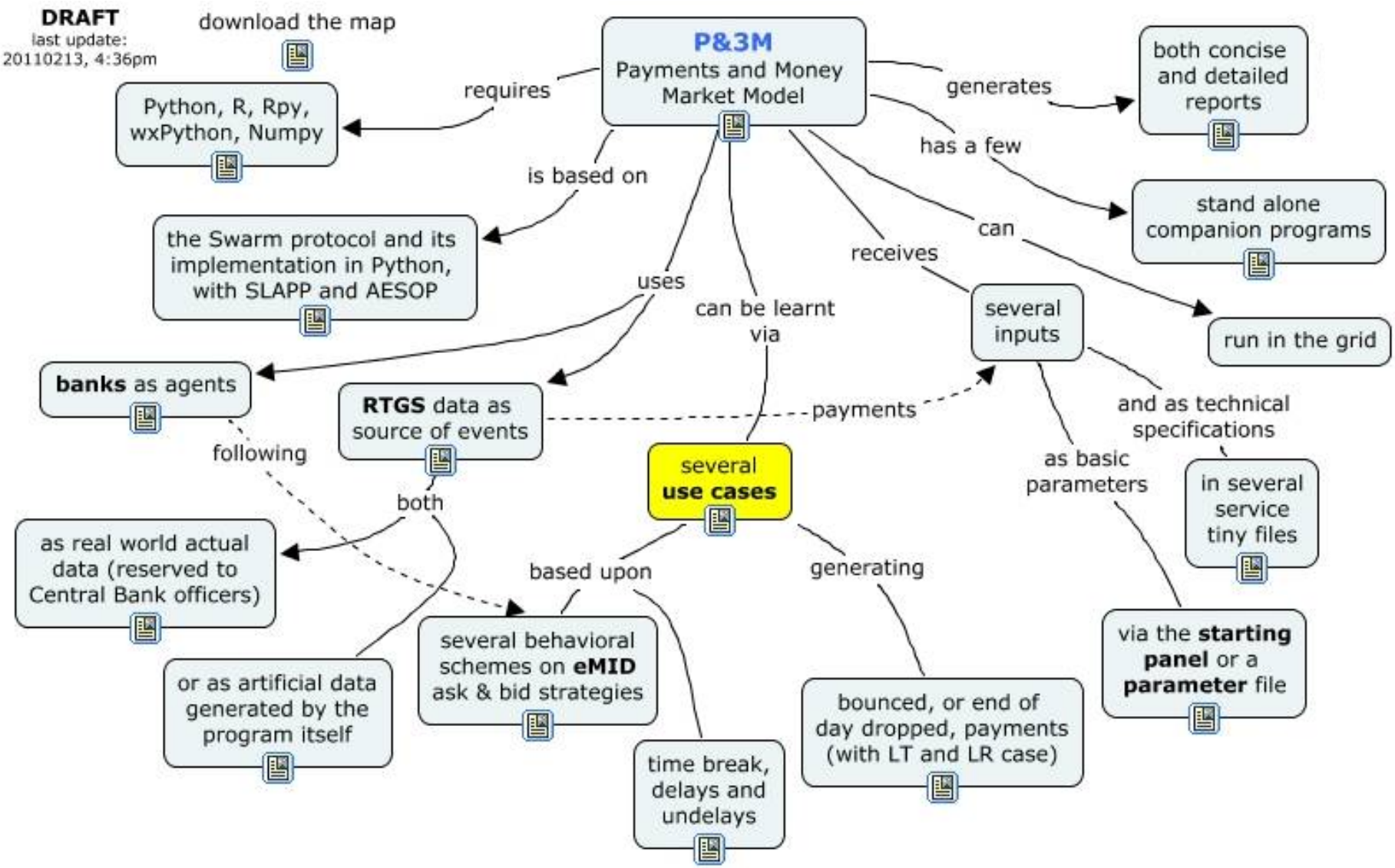
Phillips' machine provided inspiration for this Emett cartoon, which appeared in Punch *15 April 1953.*

Moving to an actual scale model of the same problem, with a conceptual map showing the structure of the model and of its "making of", at

http://eco83.econ.unito.it/terna/P&3M/P&3M.html

with a basic formal description (with Bank of Italy colleagues: Luca Arciero, Claudia Biancotti, Leandro D'Aurizio, Giuseppe Ilardi, Claudio Impenna, Cristina Picillo, at

http://eco83.econ.unito.it/terna/abm-baf09/abstracts_papers/Ilardi%28paper%29_ABM-BaF09.pdf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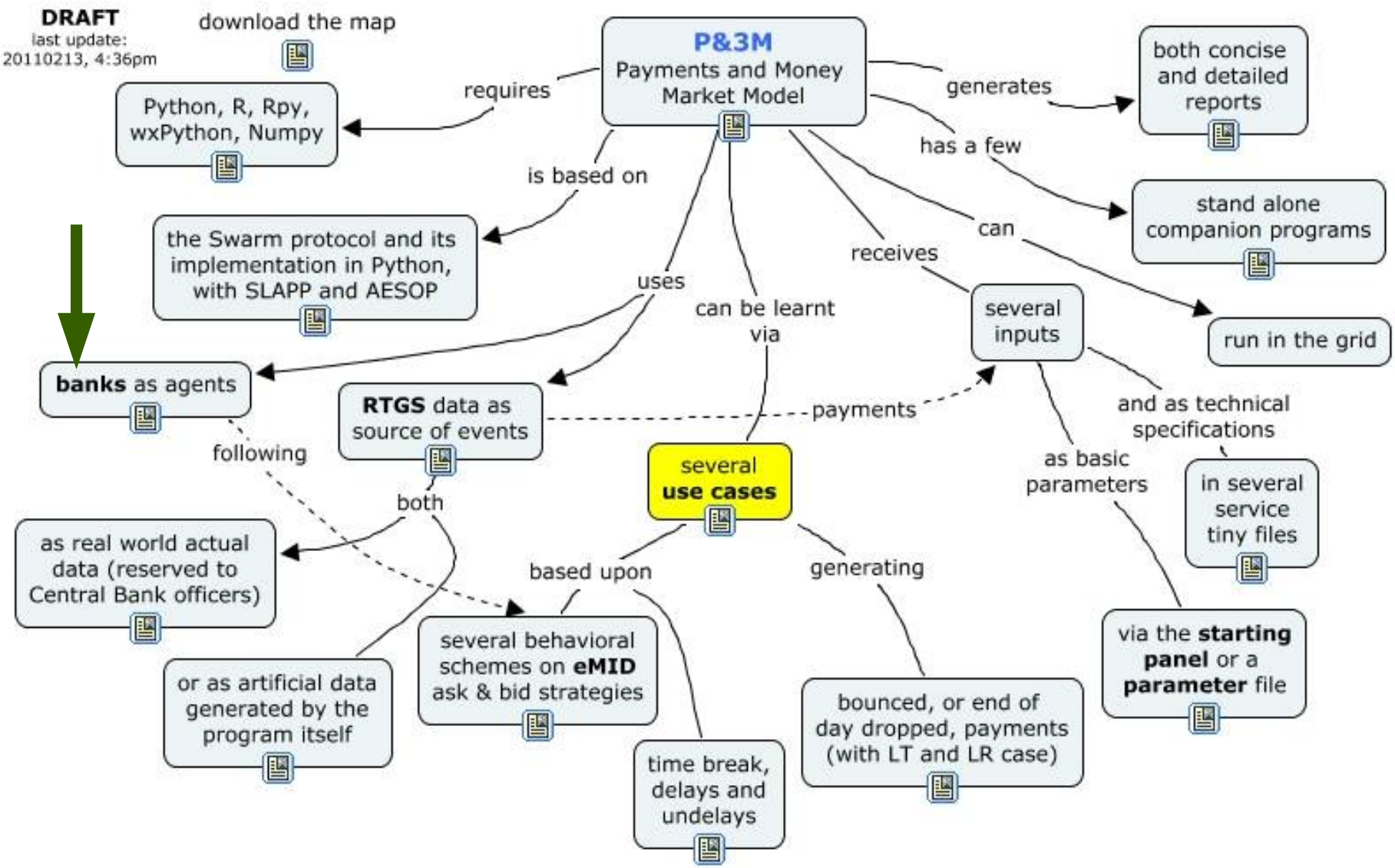
download the map
P&3M
Payments and Money Market Model
requires
Python, R, Rpy, wxPython, Numpy
generates
both concise and detailed reports
has a few
stand alone companion programs
is based on
the Swarm protocol and its implementation in Python, with SLAPP and AESOP
uses
can be learnt via
receives
can
run in the grid
several inputs
banks as agents
RTGS data as source of events
payments
and as technical specifications
following
several use cases
as basic parameters
in several service tiny files
both
as real world actual data (reserved to Central Bank officers)
based upon
generating
via the starting panel or a parameter file
or as artificial data generated by the program itself
several behavioral schemes on eMID ask & bid strategies
bounced, or end of day dropped, payments (with LT and LR case)
time break, delays and undelays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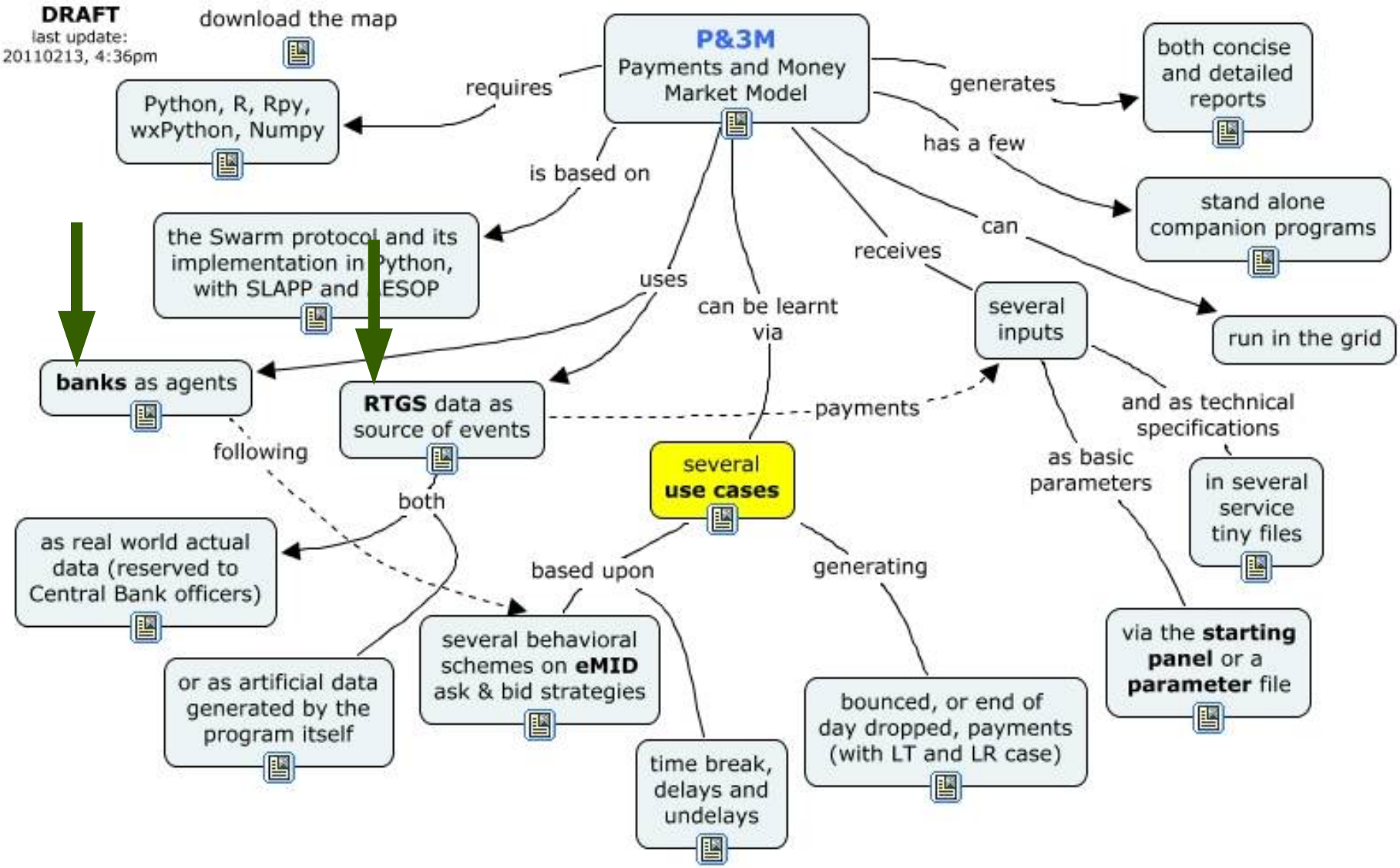
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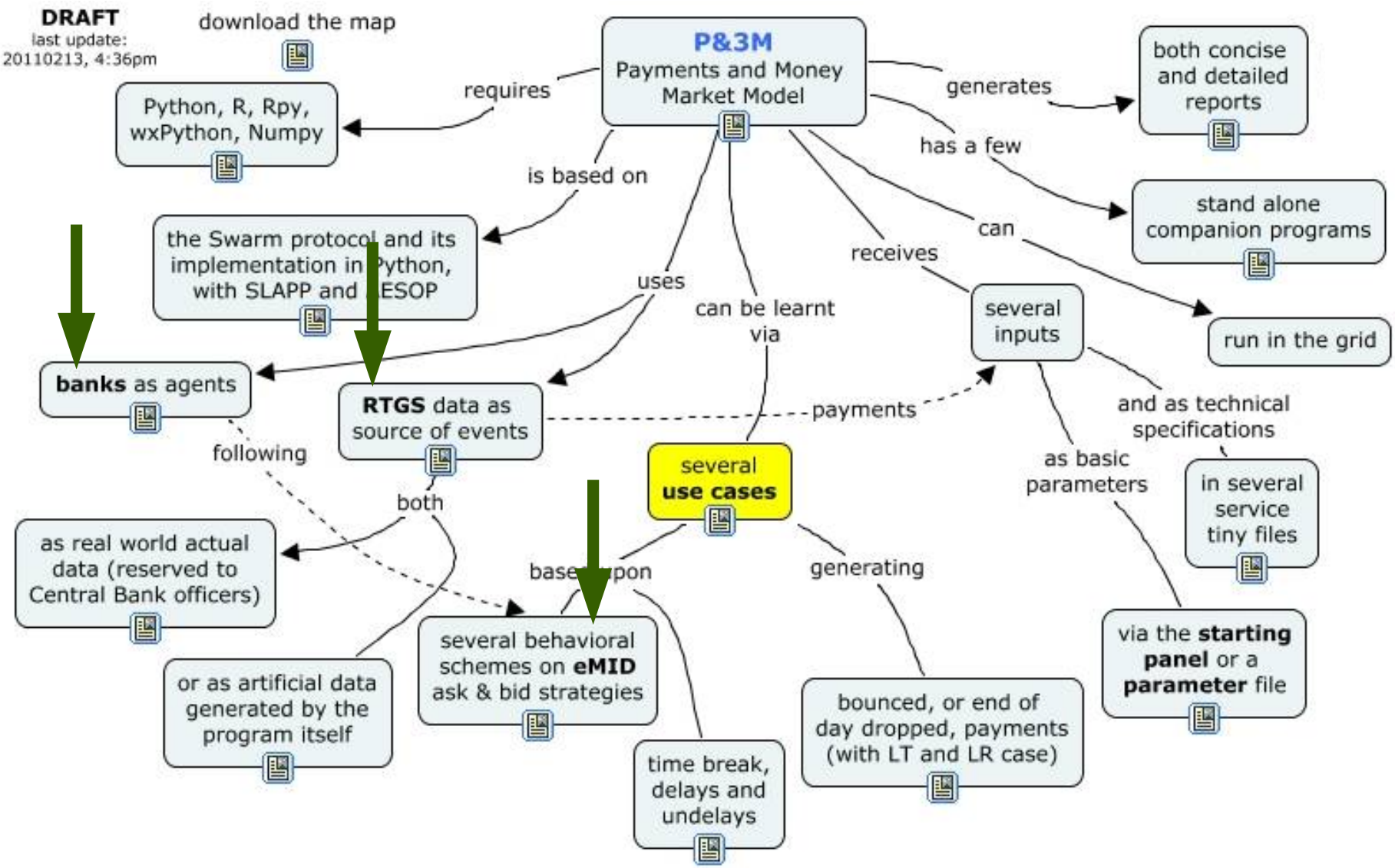
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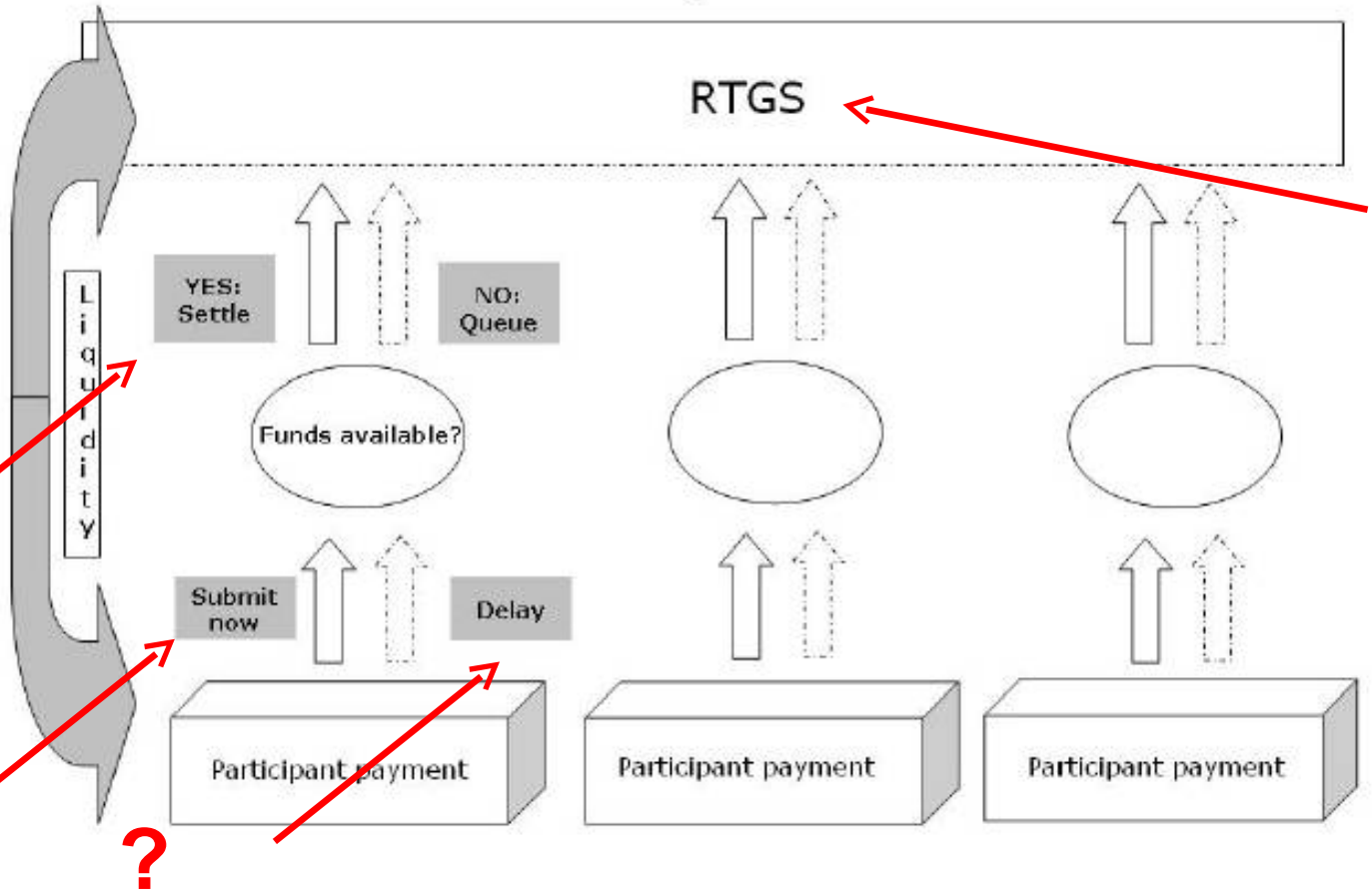
The Italian Central Bank model of the internal interbank payment system

Basic functioning of an RTGS environment



Real Time Gross Settlement payment system

Automatic settlements

Treasurers' decisions

?

This figure, related to a StarLogo TNG implementation of the model, comes from: Luca Arciero+, Claudia Biancotti*, Leandro D'Aurizio*, Claudio Impenna+ (2009), as in slide 4.

+ 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

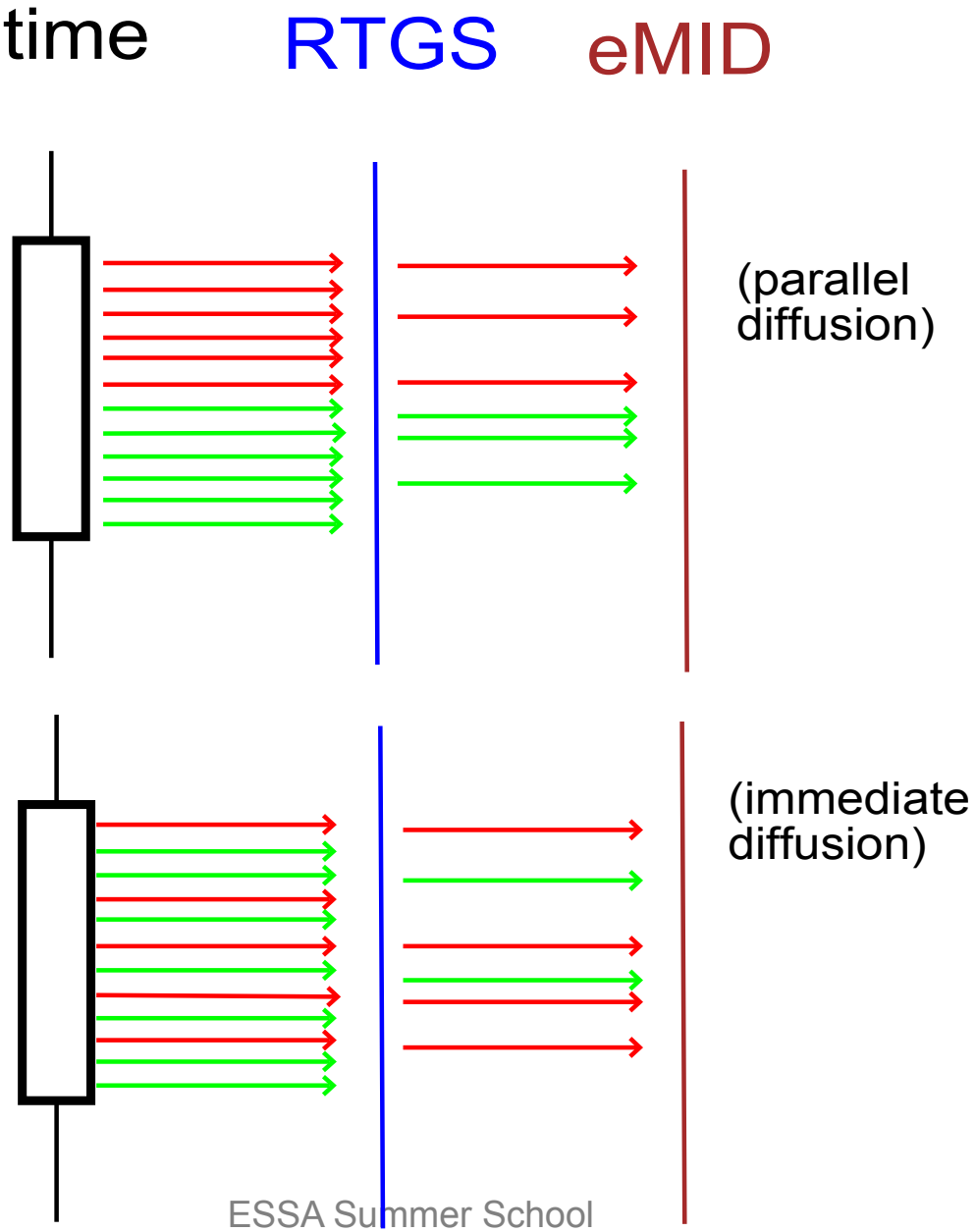
The Italian Central Bank model:

a few complicated microstructures

A treasurer making a payment: she bids a price to obtain money with P = p

A treasurers receiving a payment: she asks a price to employ money with P = p

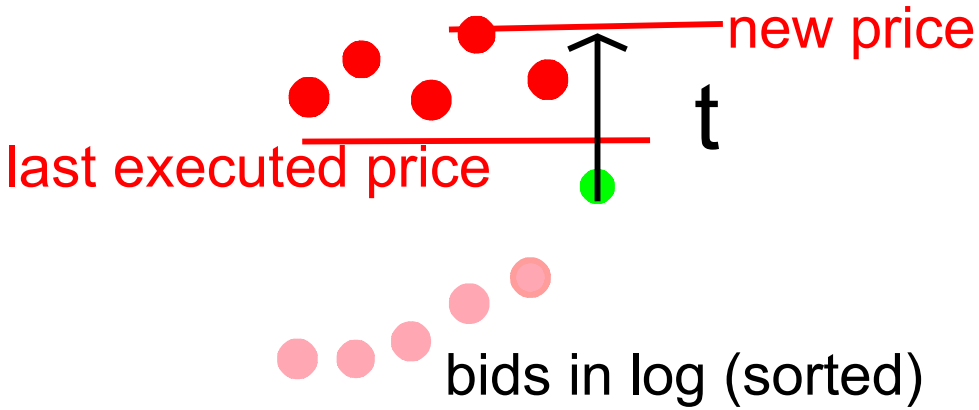
A "quasi UML" representation



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

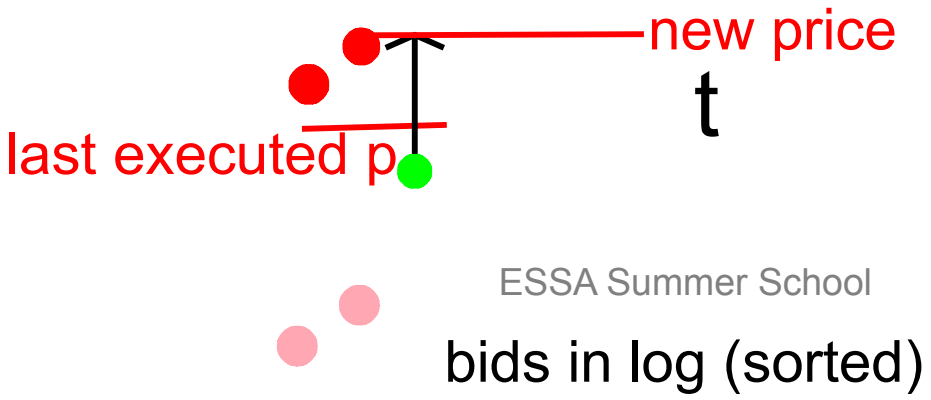
ask bid

parallel payment diffusion, looking at the last executed price



ask bid

immediate payment diffusion, looking at the last executed price

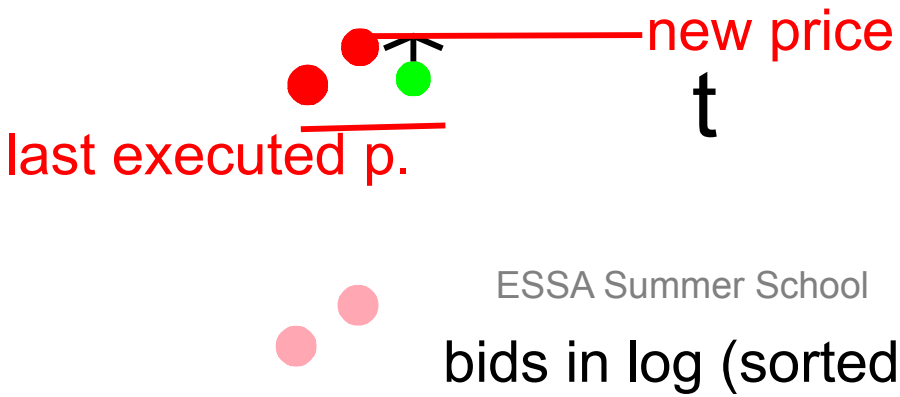


ask bid

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

ask bid

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



A technical digression

SLAPP, or Swarm-Like Agent Protocol in Python, is a simplified implementation of the original Swarm protocol, choosing Python as a simultaneously simple and complete object-oriented framework.

The SWARM protocol

SLAPP is **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 container:

the Swarm protocol

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

modelSwarm

create agents

create actions

run modelSwarm

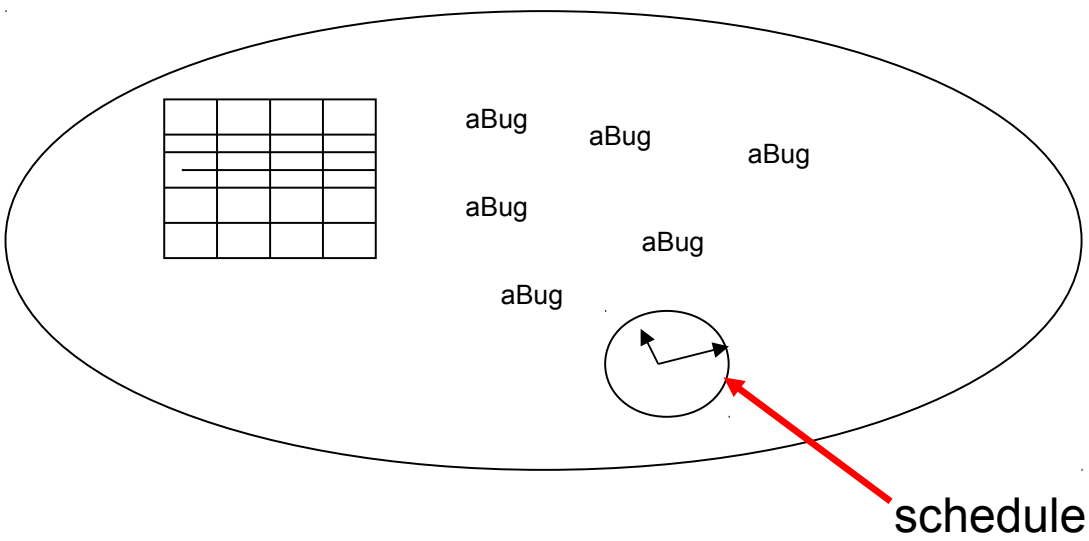
Bug

aBug

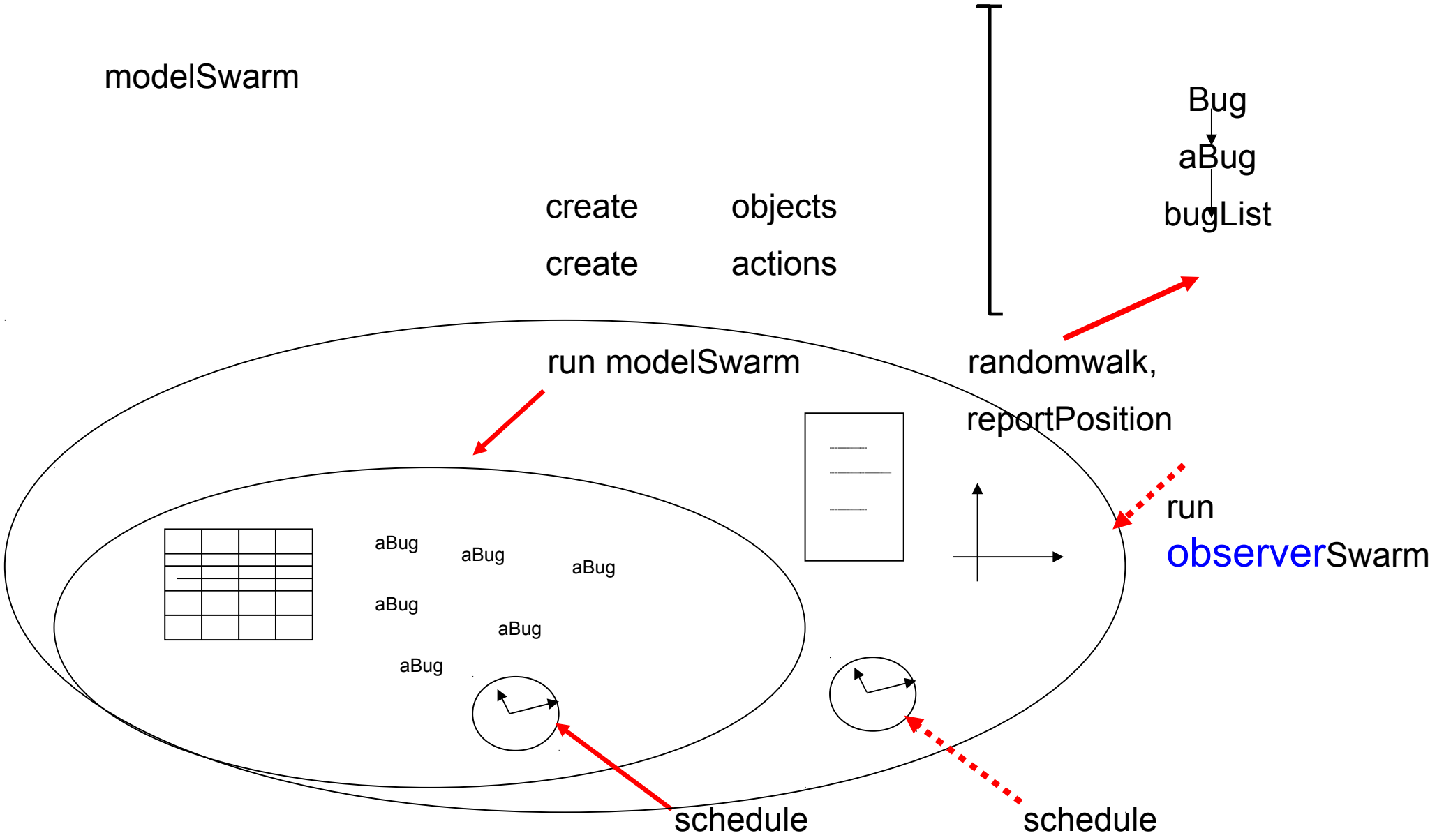
bugList

randomwalk,

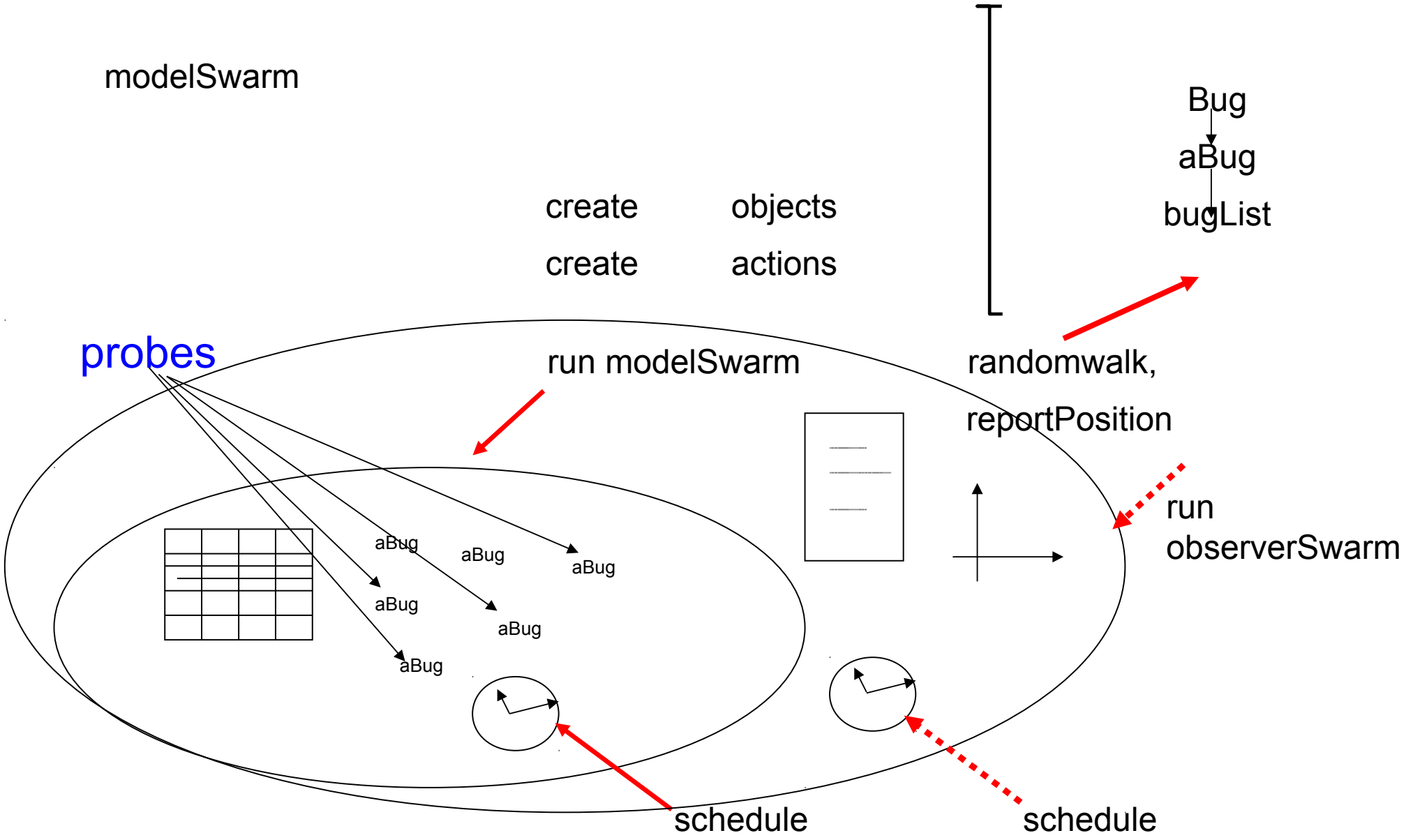
reportPosition



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



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



The content:

the ERA scheme (Environment, Agents and Rules)

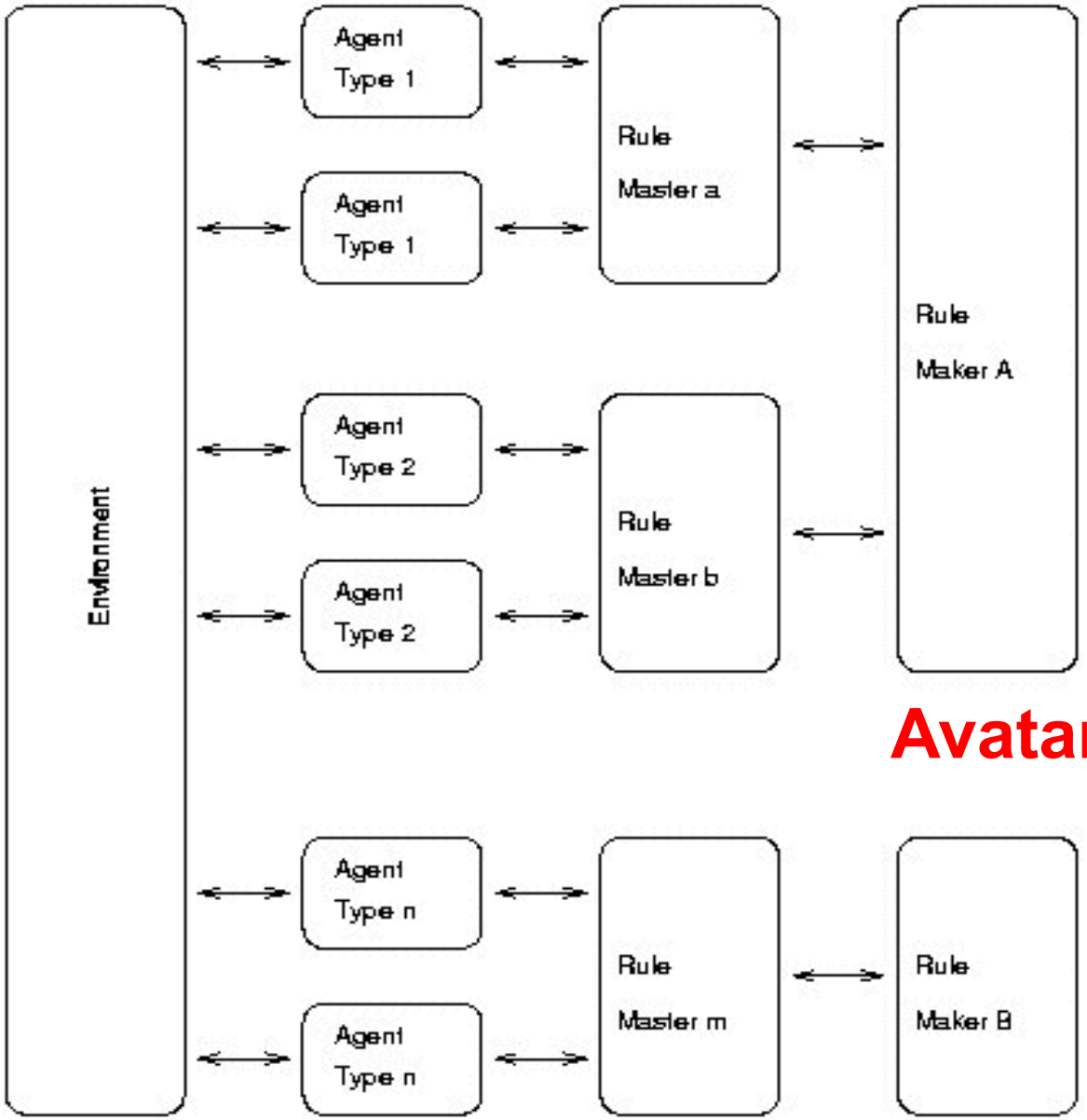
ERA

N.Gilbert, P.Terna (2000), How to build and use agent-based models in social science, Mind & Society, no. 1, pp.57-72

or

N.Gilbert, P.Terna (2010), How to build and use agent-based models in social science. In Nigel Gilbert (ed.) Computational Social Science, Sage Pubblications London, Vol. IV, pp.229-246

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



Fixed rules

NN

CS

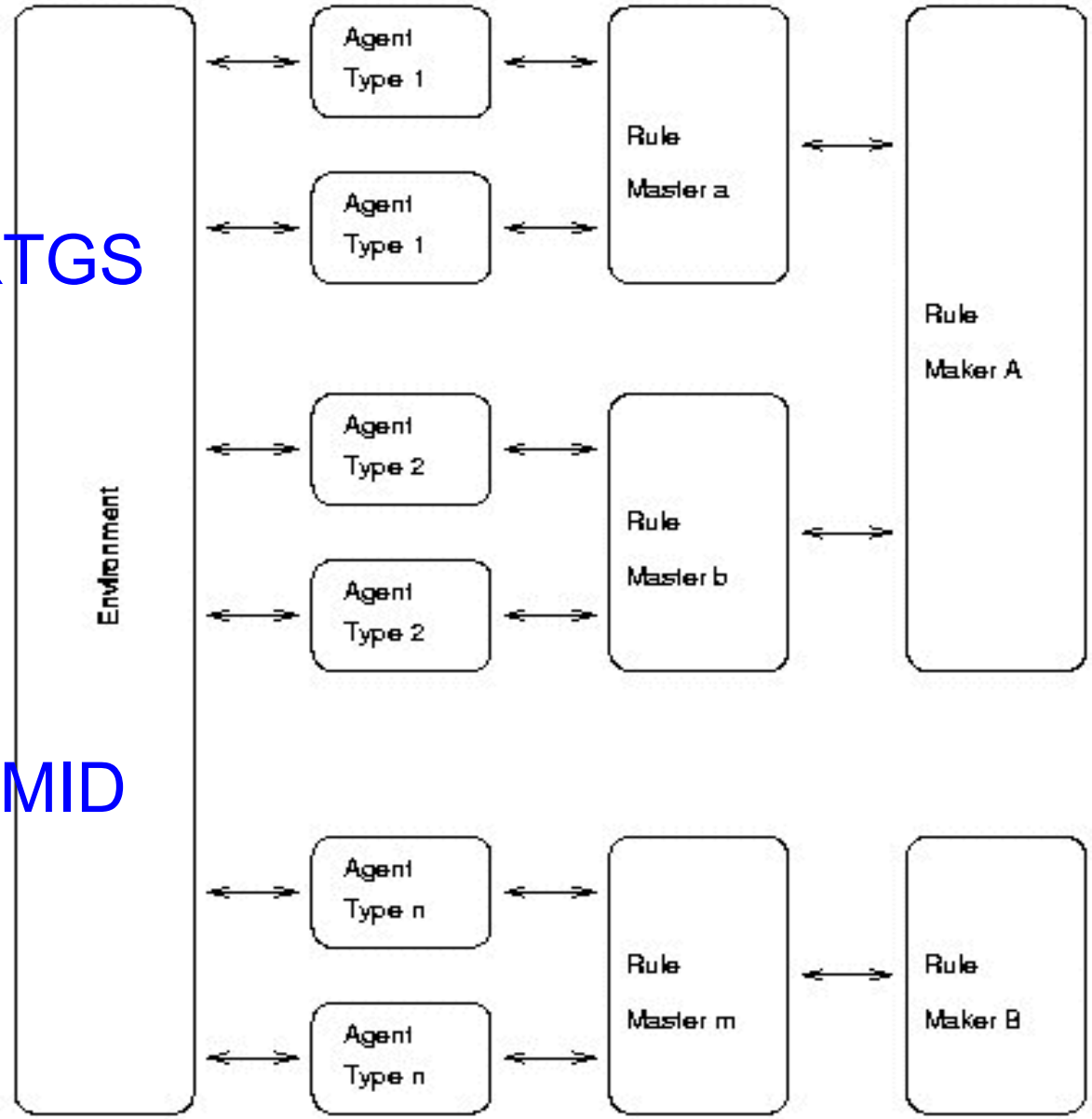
GA

Reinforcement learning

Avatar

RTGS

eMID


Environment
Agent Type 1
Agent Type 1
Agent Type 2
Agent Type 2
Agent Type n
Agent Type n
Rule Master a
Rule Master b
Rule Master m
Rule Maker A
Rule Maker B

The search for an equilibrium between the "simple" equation based description of the of the banks and the "complicated" definition of the micro-details in their actions

the search for an equilibrium between:

the *"simple" equation based description* of the behavior of the banks' treasurers

and the complexity arising from a *"complicated" definition of the micro-details in their actions*

From abstraction to realism

(i)

The standard economic approach tries to compress the complexity of the reality into the mathematical structure of models based on ex ante hypotheses arising from the standard paradigms, as the rationality in behavior, so ignoring interaction and sociality among the real world agents.

The use of those models, for individual and collective choices, determines the ineffectiveness of corrective actions in policies.

(ii)

The first step in a pro-social direction is to bring the equations of the models

at the level of individual agents,
possibly with some degree of heterogeneity,
closer both to realism and social dimension;

especially in the presence of heterogeneity, it is a step ahead the pure numerical simulation, but still too tied to the standard paradigm.

(iii)

If the stylized agents, with their equations, operate (calculate) in a system with institutions (for example, a trading system), the model is taking another step forward realism and usefulness.

(iv)

Finally, it is only with a full implementation of the ABM paradigm that we can respond to the needs expressed by policy maker calling, as Trichet (2010 [http://www.ecb.int/press/key/date/2010/html/sp101118.en.html]), for a radical change in the models.

A whole line of work

A huge work awaits us: the construction of models that can compare in a parallel way

(i) the standard setting of the purely mathematical model, with equations that reproduce the behavior in a decentralized way,

in case (ii) also with heterogeneity, and

in case (iii) through interaction with institutions and rules, until

the use (iv) of models completely based on agents, both with simple behavioral skills or with arbitrarily complicated way of behaving.

Those skills are related to the structures of relationships, mutual influence, information, ...

A technical appendix

The current package for ”Agent based simulation model of RTGS system and money market”, or Payments and Money market model (in short: P&3M), is a special implementation of SLAPP.

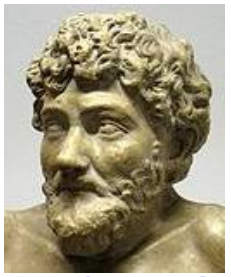
In perspective, it will evolve to a (special) AESOP application.

SLAPP

SLAPP, Swarm-Like Agent Protocol in Python, as a simplified implementation of the original Swarm protocol, choosing Python as a simultaneously simple and complete object-oriented framework.

The SLAPP project has also the goal of offering to scholars interested in agent-based models a set of programming examples that could be easily understood in all their details and adapted to other applications.

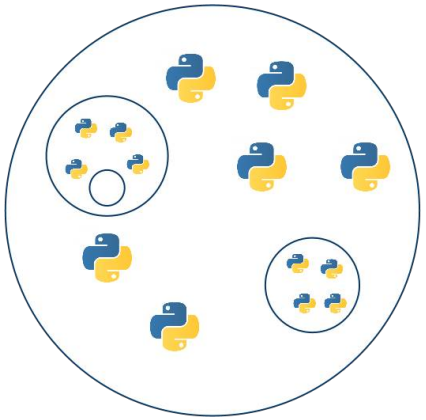
AESOP



AESOP, Agents and Emergencies for Simulating Organizations in Python), written upon SLAPP and intended to be a simplified way to describe and generate interaction within artificial agents.

- bland agents (simple, unspecific, basic, insipid, …) used to populate our simulated world with agents doing basic actions;
- tasty agents (specialized, with given skills, acting in a discretionary way, …), used to specify important roles into the simulation scenario.

2011 SwarmFest



A huge surprise: thanks to Steve Rogers, we will have a parallel SLAPP implementation, running within **0MQ**,

http://zeromq.org/

http://www.youtube.com/watch?v=_JCBphyciAs

So … **0**SLAPP is born

(see http://code.google.com/p/slapp-tools/).

A quick look to SLAPP

Swarm-Like Agent Based Protocol in Python

Why a new tool?

- For didactical reasons, applying a such rigorous and simple object oriented language as Python is
- To build models upon transparent code: Python does not have hidden parts or features coming from *magic*, it has no obscure libraries
- **To use the openness of Python**
- **To have the possibility of using the key feature of the Swarm protocol in an easy way**

About Python and ABMs have also a look to

the 2011 Alan Isaac paper at

http://jasss.soc.surrey.ac.uk/14/2/5.html

Alan G. Isaac (2011)

The ABM Template Models: A Reformulation with Reference Implementations

Journal of Artificial Societies and Social Simulation **14** (2) 5
<http://jasss.soc.surrey.ac.uk/14/2/5.html>

The openness of Python (www.python.org)

- … going from Python to R
  (R is at http://www.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 and LibreOffice)

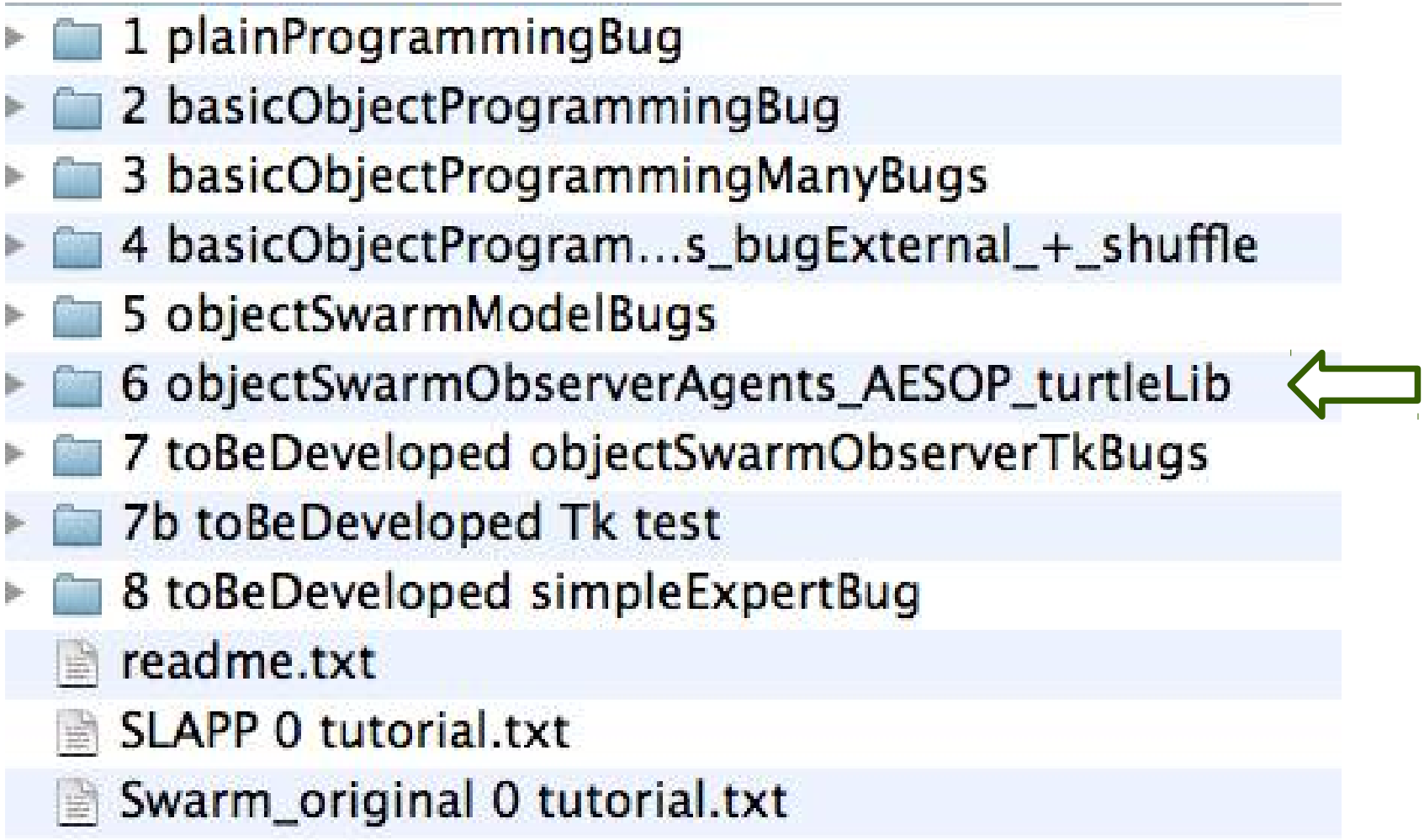
- … doing symbolic calculations in Python (via http://code.google.com/p/sympy/)

- … doing declarative programming with PyLog, a Prolog implementation in Python (http://www.cdsoft.fr/pylog/index.html)

- … using Social Network Analysis from Python; examples:
- Igraph http://cneurocvs.rmki.kfki.hu/igraph/
- NetworkX http://networkx.lanl.gov/

The SLAPP package at

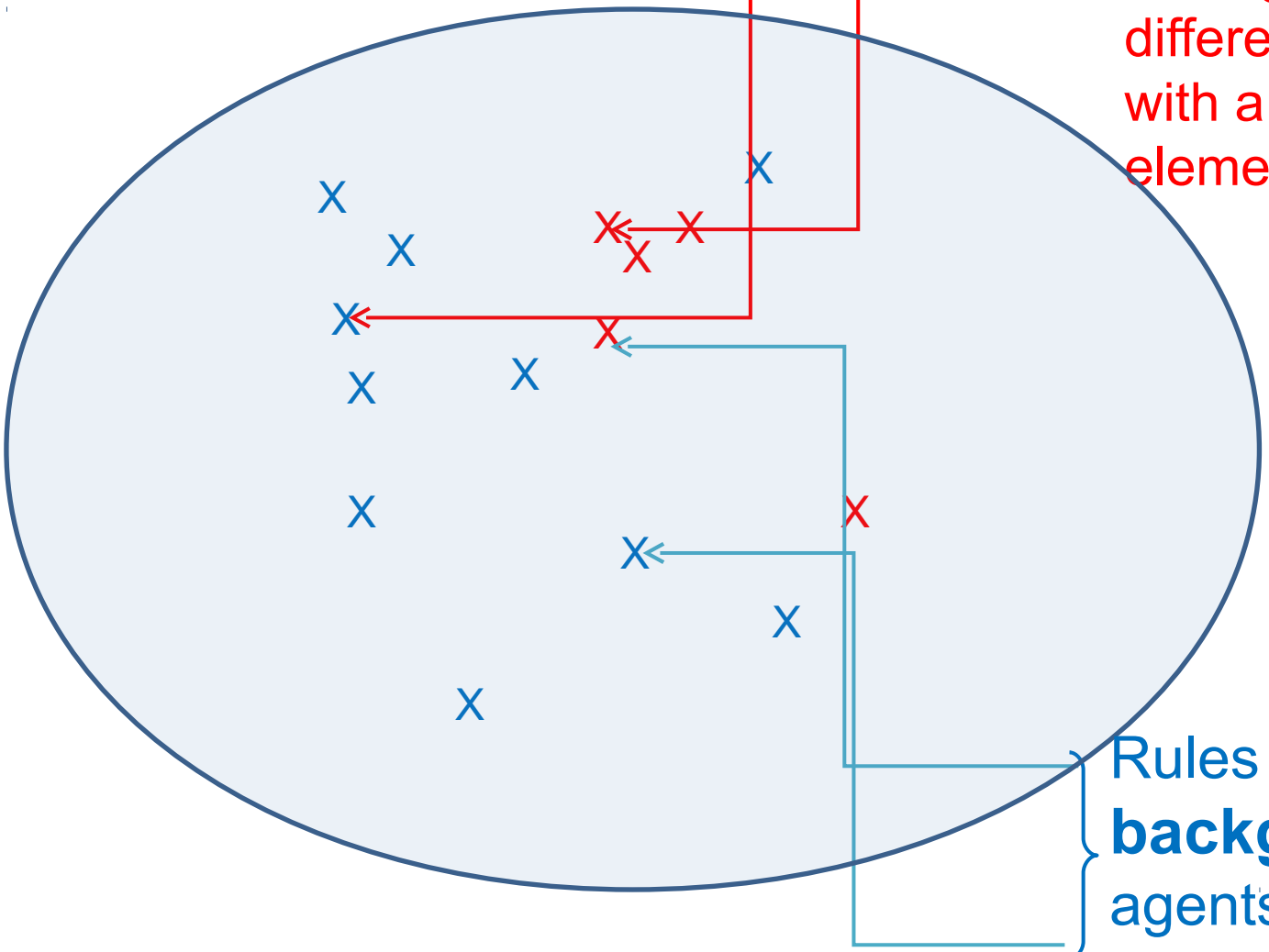
http://eco83.econ.unito.it/terna/slapp


1 plainProgrammingBug
2 basicObjectProgrammingBug
3 basicObjectProgrammingManyBugs
4 basicObjectProgram…s_bugExternal_+_shuffle
5 objectSwarmModelBugs
6 objectSwarmObserverAgents_AESOP_turtleLib
7 toBeDeveloped objectSwarmObserverTkBugs
7b toBeDeveloped Tk test
8 toBeDeveloped simpleExpertBug
readme.txt
SLAPP 0 tutorial.txt
Swarm_original 0 tutorial.txt


a_note_on_AESOP.txt
ActionGroup.py
basic
convert_xls_txt.py
ModelSwarm.py
ObserverSwarm.py
Pen.py
school
SLAPP 6 objectSwarmObserverAgents.txt
start 6 objectSwarmObserverAgentsAESOP.py
Swarm_original 7 simpleObserverBug.txt
Swarm_original 8 simpleObserverBug2.txt
Tools.py
WARNING.txt

Agents and schedule

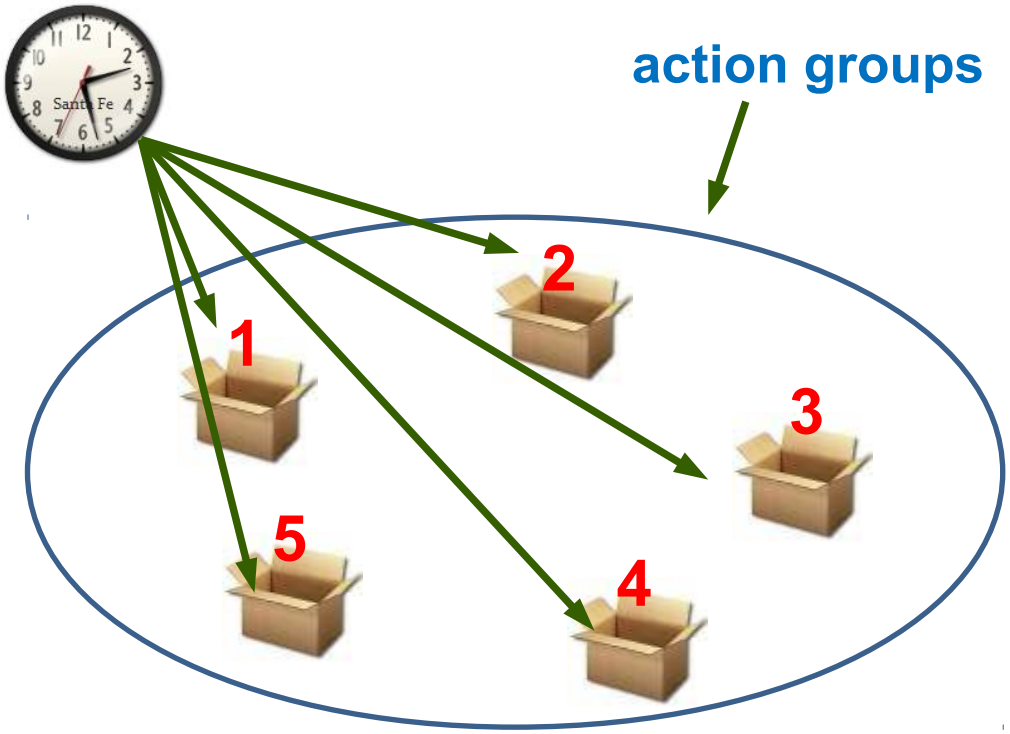
Bland* and **tasty#** agents



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 or for a specific set of tasty agents

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



What in each box?

Tasks to be executed (with p=1 or with p<1)

Tasks are included into the code in a static way, or can be added/activated dynamically by other tasks, also via agents' actions

Tasks can be read – via a 'read' task schedule element – from an external source (file, web interaction, …)

A special type of task to be read from an external source is that of the recipes

tasks read from an external archive

a_n – a specific agent (instance of class A)
a_X – a randomly chosen agent (instance of class A)
a_%all – a quota of all the agents (instances) of the class A
a_all – all the agents (instances) of the class A

methods specific of each agent or inherited from the basic types ‘Agent’ or 'Turtle'

recipes, as macro, read from an external archive

[[agent method] [agent method] [agent method] [agent method] [agent method] …]

→ to be executed in a sequential way by a given thread of agents (statically or dynamically)

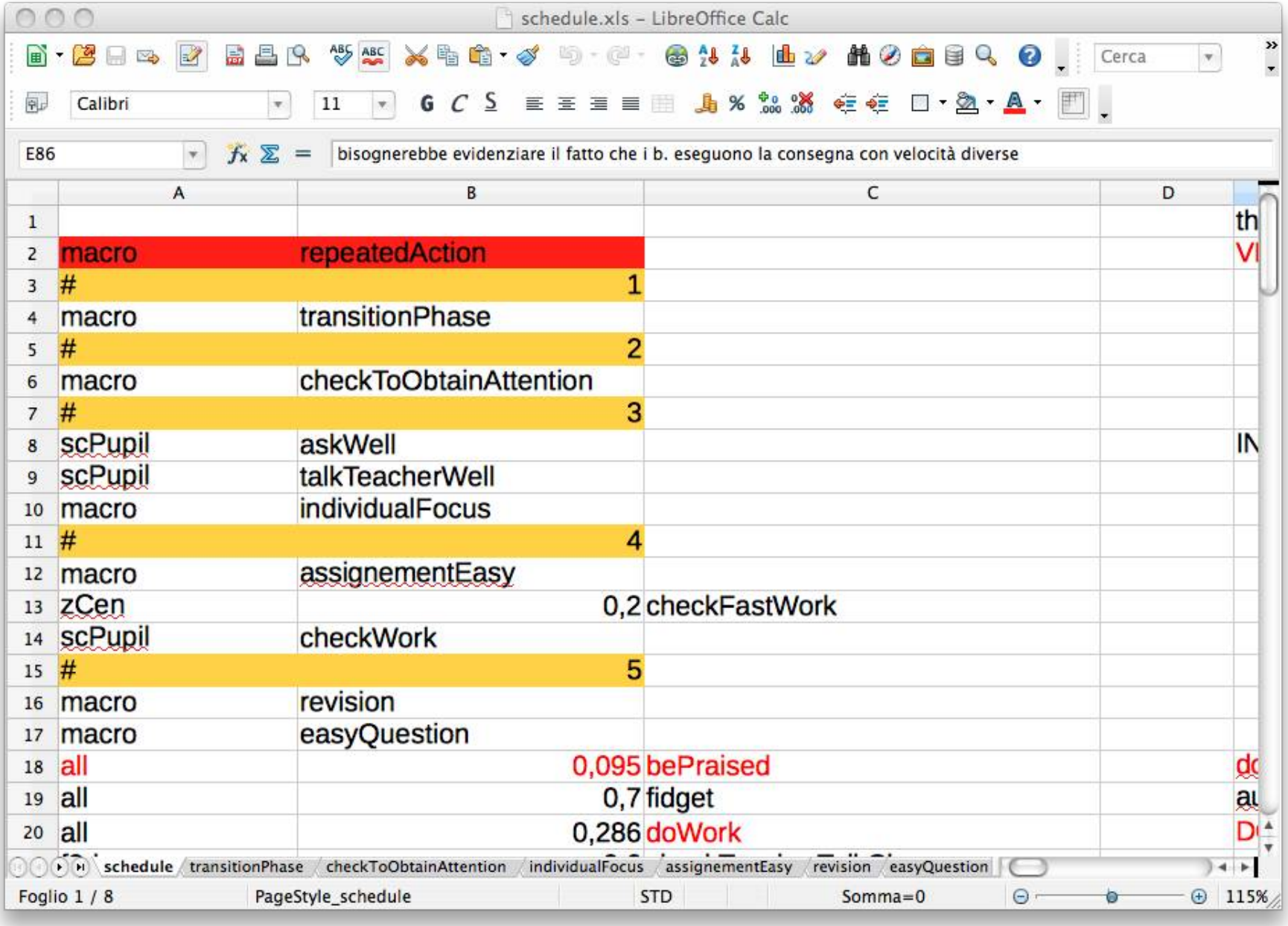
[[agent method] **[**[agent method] [agent method] [agent method]**]** [agent method] …]

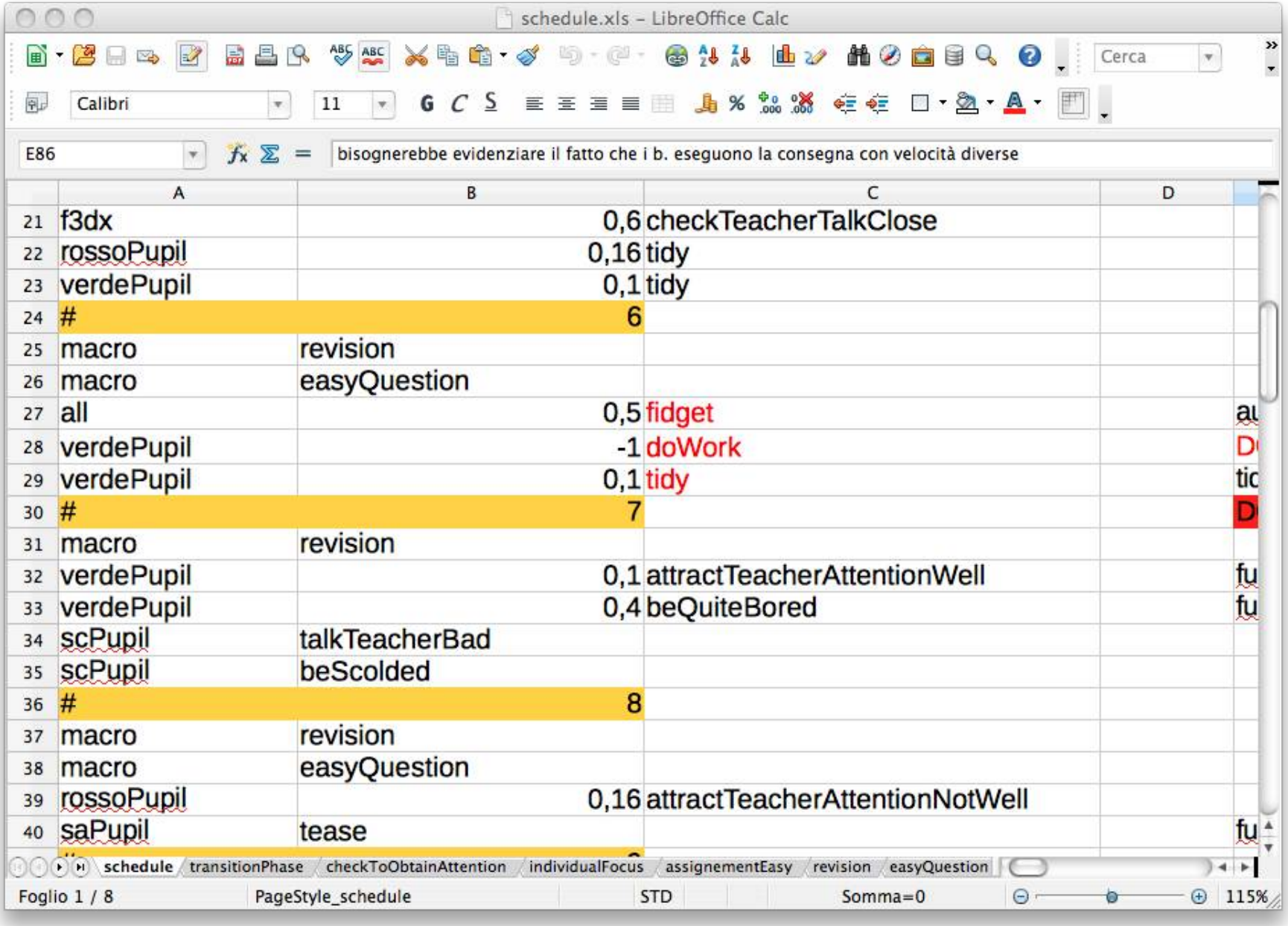
with segments to be executed in a parallel way

[[agent method] [agent method] **N**[agent method] [agent method] [agent method] …]
[:::::::::::::::::::::::::::::::::::: : [agent method] :::::::::::::::::::::::::::::::::::: …]
[:::::::::::::::::::::::::::::::::::: :: …]
[:: [agent method] :::::::::::::::::::::::::::::::::::: …]

with components belonging to different recipes to be executed as a whole

An example, studying pupils behavior in primary school classes (with Sandro Brignone, Aldo Milano and Tiziana Pasta)


schedule.xls – LibreOffice Calc
Cerca
Calibri
11
E86
bisognerebbe evidenziare il fatto che i b. eseguono la consegna con velocità diverse
A
B
C
D
1
2 macro repeatedAction
3 # 1
4 macro transitionPhase
5 # 2
6 macro checkToObtainAttention
7 # 3
8 scPupil askWell
9 scPupil talkTeacherWell
10 macro individualFocus
11 # 4
12 macro assignementEasy
13 zCen 0,2 checkFastWork
14 scPupil checkWork
15 # 5
16 macro revision
17 macro easyQuestion
18 all 0,095 bePraised
19 all 0,7 fidget
20 all 0,286 doWork
schedule
transitionPhase
checkToObtainAttention
individualFocus
assignementEasy
revision
easyQuestion
Foglio 1 / 8
PageStyle_schedule
STD
Somma=0
115%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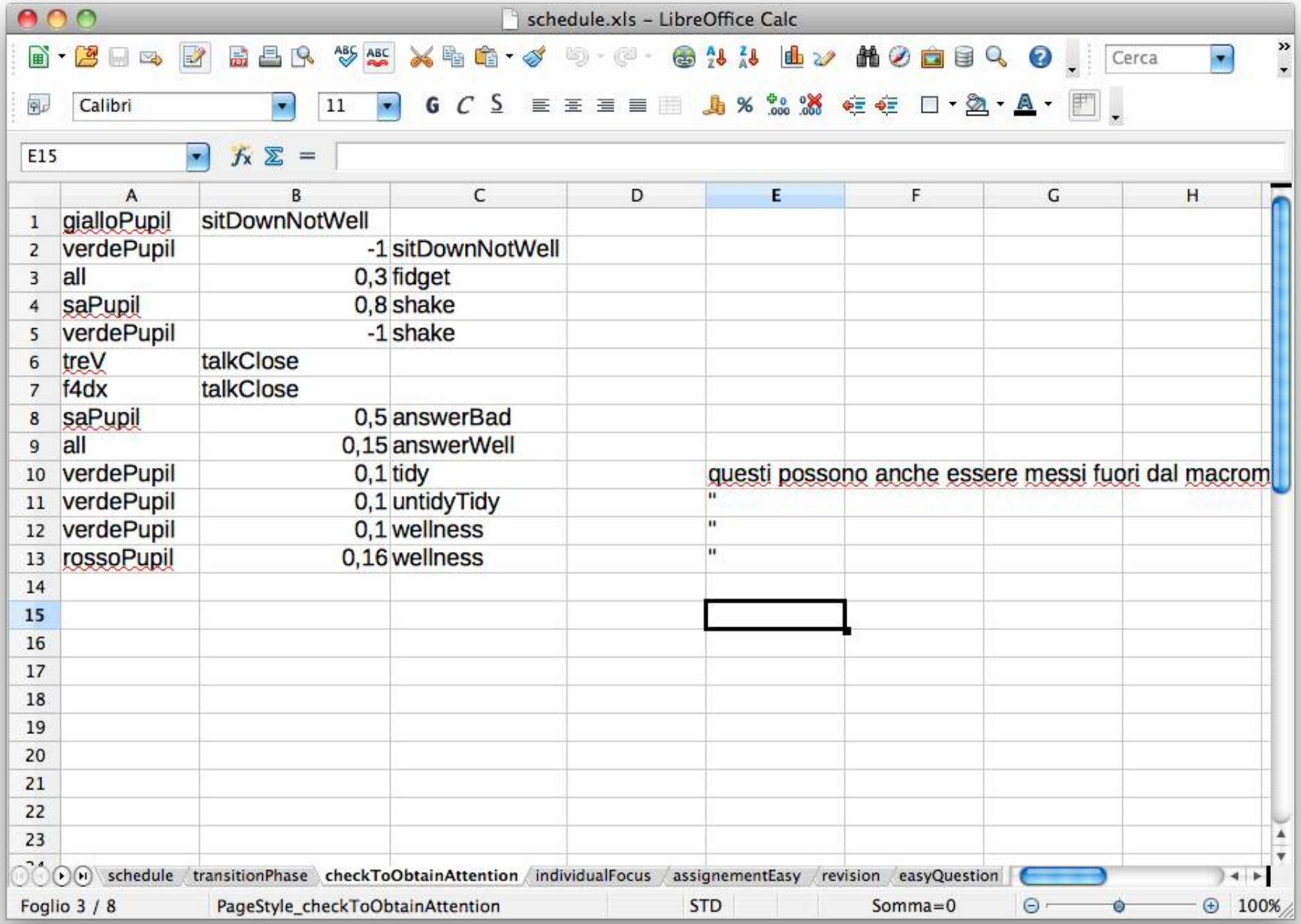
A
B
C
D
21 f3dx 0,6 checkTeacherTalkClose
22 rossoPupil 0,16 tidy
23 verdePupil 0,1 tidy
24 # 6
25 macro revision
26 macro easyQuestion
27 all 0,5 fidget
28 verdePupil -1 doWork
29 verdePupil 0,1 tidy
30 # 7
31 macro revision
32 verdePupil 0,1 attractTeacherAttentionWell
33 verdePupil 0,4 beQuiteBored
34 scPupil talkTeacherBad
35 scPupil beScolded
36 # 8
37 macro revision
38 macro easyQuestion
39 rossoPupil 0,16 attractTeacherAttentionNotWell
40 saPupil tease
schedule
transitionPhase
checkToObtainAttention
individualFocus
assignementEasy
revision
easyQuestion
Foglio 1 / 8
PageStyle_schedule
STD
Somma=0
115%



	A	B	C	D	E	F	G	H
1	gialloPupil	sitDownNotWell						
2	verdePupil	-1	sitDownNotWell					
3	all	0,3	fidget					
4	saPupil	0,8	shake					
5	verdePupil	-1	shake					
6	treV	talkClose						
7	f4dx	talkClose						
8	saPupil	0,5	answerBad					
9	all	0,15	answerWell					
10	verdePupil	0,1	tidy		questi possono anche essere messi fuori dal macrom			
11	verdePupil	0,1	untidyTidy		"			
12	verdePupil	0,1	wellness		"			
13	rossoPupil	0,16	wellness		"			
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								

Thanks

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