Vilfredo Pareto Doctorate in Economics (Economics and Complexity) – Master in Data Science for Complex Economic Systems – Allievi Honors Program

Agent-Based Models - Introductory notes

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course material at http://terna.to.it/sim/2016/

Introductory material:

- P. Terna (2013), A Complex Lens for Economics, or: About Ants and their Anthill, in “Spazio filosofico”, 7, pp. 167-177
  http://www.spaziofilosofico.it/wp-content/uploads/2013/01/Terna-English.pdf

- P. Terna (2013), Learning agents and decisions: new perspectives, in "Law and Computational Social Science", 1, http://terna.to.it/materiale/terna_def.pdf

- A. Ghorbani, F. Dechesne, V. Dignum, and C. Jonker (2014), Enhancing ABM into an Inevitable Tool for Policy Analysis, in “Policy and Complex Systems”, 1(1):61–76, 2014,
  http://www.ipsonet.org/publications/open-access/policy-and-complex-systems/volume-1-number-1-spring-2014

A quite new inspiring article:

- Alan Kirman. Complexity and Economic Policy: A Paradigm Shift or a Change in Perspective? A Review Essay on David Colander and Roland Kupers's Complexity and the Art of Public Policy.
  Journal of Economic Literature, 54(2):534–572, 2016.
  http://www.rolandkupers.com/wp/wp-content/uploads/2016/06/JEL-Kirman.pdf

Collegio Carlo Alberto
UNIVERSITÀ DEGLI STUDI DI TORINO

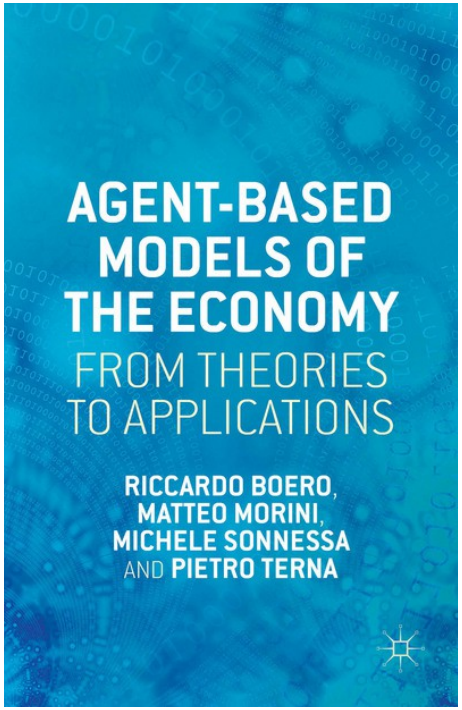
Introductory material:

Agent-based Models of the Economy

From Theories to Applications

Riccardo Boero, Matteo Morini, Michele Sonnessa, Pietro Terna

ISBN	9781137339805
Publication Date	June 2015



A nice definition:

- R. L. Axtell and J. M. Epstein. Coordination in transient social networks: an agent-based computational model of the timing of retirement. In J. M. Epstein, editor, Generative social science: Studies in agent- based computational modeling, page 146. Princeton University Press, 2006.

On line

http://www.econ.tuwien.ac.at/lva/compeco.se/artikel/epstein_coordination_in_transient_social_networks.pdf

Look at p.6 on line

A nice definition:

Compactly, in agent-based computational models a population of data structures representing individual agents is instantiated and permitted to interact.

One then looks for systematic regularities, often at the macro-level, to emerge, that is, arise from the local interactions of the agents.

The short-hand for this is that macroscopic regularities "grow" from the bottom-up. No equations governing the overall social structure are stipulated in multi-agent computational modeling, thus avoiding any aggregation or misspecification bias.

A nice definition (cont.):

Typically, the only equations present are those used by individual agents for decision-making.

Different agents may have different decision rules and different information; usually, no agents have global information, and the behavioral rules involve bounded computational capacities—the agents are "simple".

This relatively new methodology facilitates modeling agent heterogeneity, boundedly rational behavior, non-equilibrium dynamics, and spatial processes.

A particularly natural way to implement agent-based models is through so-called object-oriented programming.

The basis

- **Artifacts** of social systems

- Leibniz (*xi. De scientia universali seu calculo philosophico*): *… quando orientur controversiae, non magis disputatione opus erit inter duos philosophos, quam inter duos computistas. Sufficiet enim calamos in manus sumere sedereque ad abbacos et sibi mutuo (...) dicere, calculemus*

- *Calculemus* or ... *Simulemus*

- ... plus complexity, bounded rationality, chaos ...

Anderson's 1972 paper "More is different" as a manifesto. In «Science», 177, 4047, pp. 393–396.

(p.393) The reductionist hypothesis may still be a topic for controversy among philosophers, but among the great majority of active scientists I think it is accepted without questions. The workings of our minds and bodies, and of all the animate or inanimate matter of which we have any detailed knowledge, are assumed to be controlled by the same set of fundamental laws, which except under certain extreme conditions we feel we know pretty well.

(…) The main fallacy in this kind of thinking is that the reductionist hypothesis does not by any means imply a "constructionist" one: The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe.

Anderson's 1972 paper "More is different" as a manifesto.

The constructionist hypothesis breaks down when confronted with the twin difficulties of scale and complexity. The behavior of large and complex aggregates of elementary particles, it turns out, is not to be understood in terms of a simple extrapolation of the properties of a few particles. Instead, at each level of complexity entirely new properties appear, and the understanding of the new behaviors requires research which I think is as fundamental in its nature as any other.

(p.396) In closing, I offer two examples from economics of what I hope to have said. Marx said that quantitative differences become qualitative ones, but a dialogue in Paris in the 1920's sums it up even more clearly:
FITZGERALD: The rich are different from us.
HEMINGWAY: Yes, they have more money.

Rosenblueth and Wiener's 1945 paper, "The Role of Models in Science", as a "manual" from the founders of cybernetics, in «Philosophy of Science», 12, 4, 316-321.

(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.

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 in the complexity perspective, building material models as artifacts running into a computer, ***having always in mind to go toward "more elaborated theoretical models"****.*

Moving to models

Building models by …

(i) words (describing, reasoning, via narratives, …)

(ii) equations

Equilibrium Models
Game Theory
System Dynamics

(iii) simulation tools

Serious Gaming
Agent-Based Simulation

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 first reply is that with agent-based models and simulation, we can produce artifacts (the 'material model') of actual systems and "play" with them, i.e., showing consequences both of **perfectly known ex-ante hypotheses** and agent behavioral design and interaction; 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.

Moving to computation:
the making of our models

Complexity, as a tool to understand reality in economics, is coming from a strong theoretical path of epistemological development.

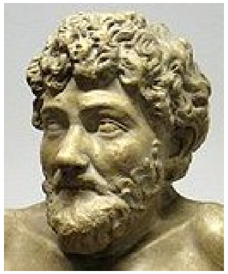
To be widely accepted, it requires a significant step ahead of the instruments we use to make computations about this class of models, with sound protocols, simple interfaces, powerful learning tools, cheap computational facilities …

Technicalities I

Why Python SLAPP and why NetLogo?

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

SLAPP is evolving to AESOP



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

- *bland* agents (simple, unspecific, basic, insipid, …) doing basic actions;
- *tasty* agents (specialized, with given skills, acting in a discretionary way, …), playing specify roles into the simulation scenario.

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 (www.swarm.org)**

. … going from Python to R
(R is at http://cran.r-project.org/ ;
PyRserve is http://packages.python.org/pyRserve/
with explanations in my Cmap (see at the end)

… going from LibreOffice/OpenOffice (Calc, Writer, …) to Python and vice versa
(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:
NetworkX http://networkx.github.io

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.santafe.edu/media/workingpapers/96-06-042.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 create 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**.*

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

modelSwarm

create agents

create actions

run modelSwarm

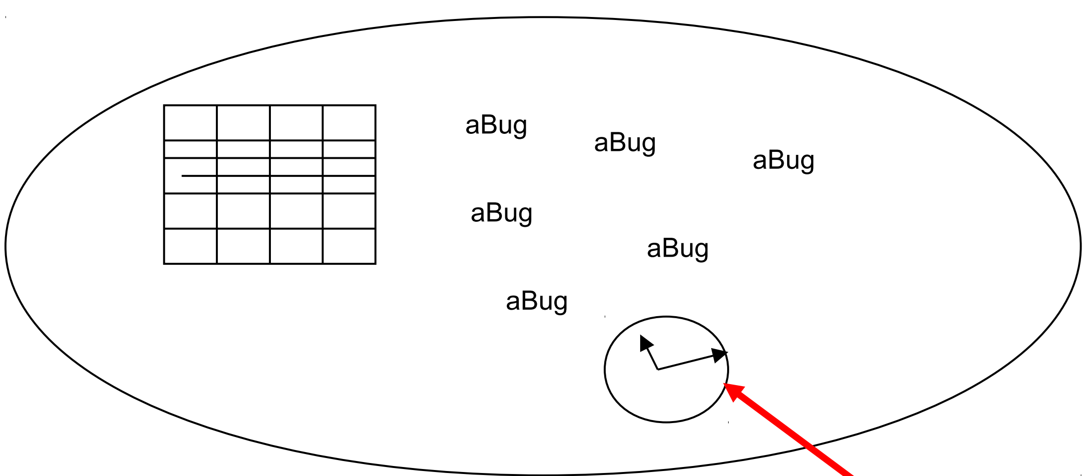
Bug

aBug

bugList

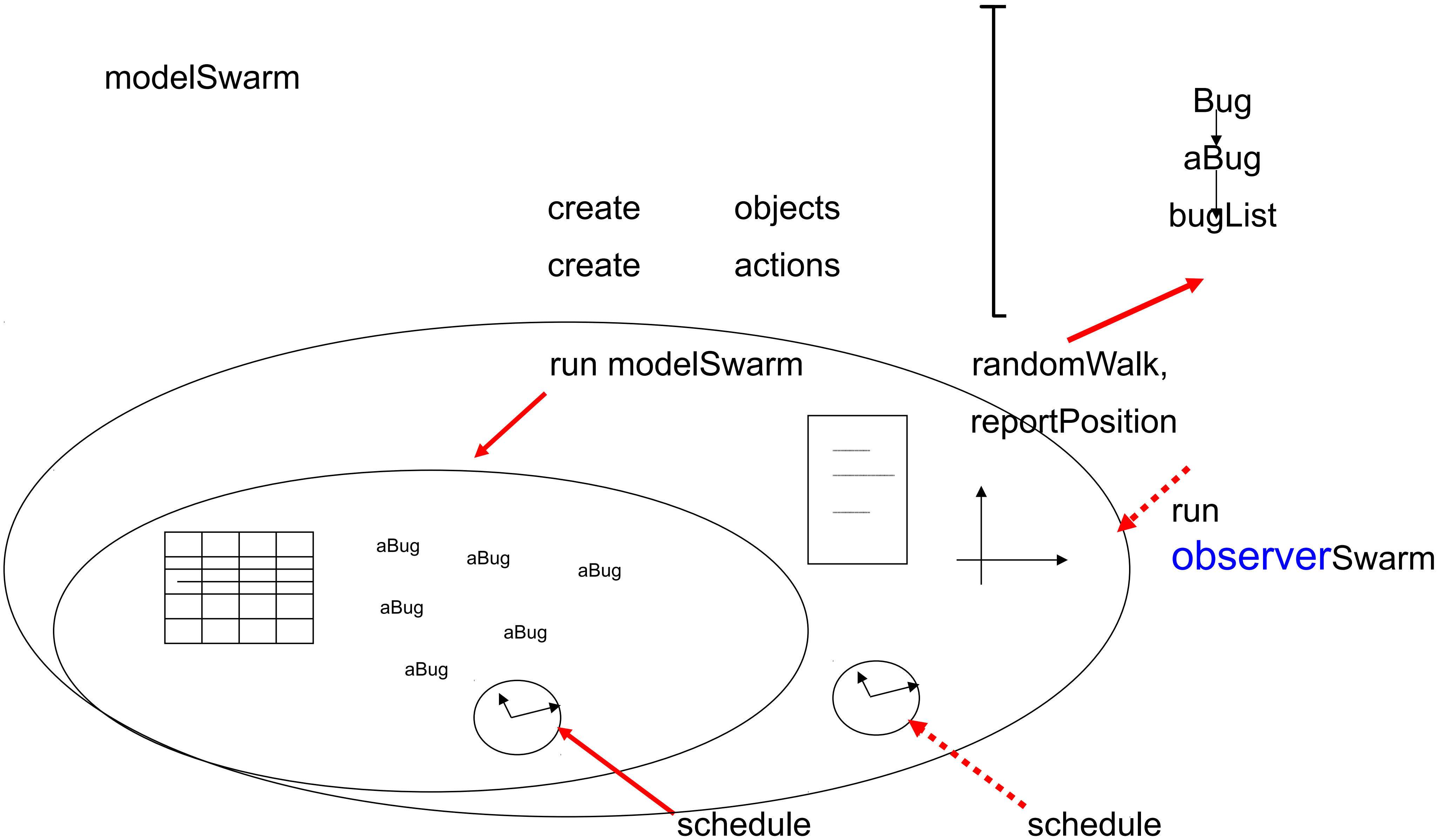
randomWalk,

reportPosition

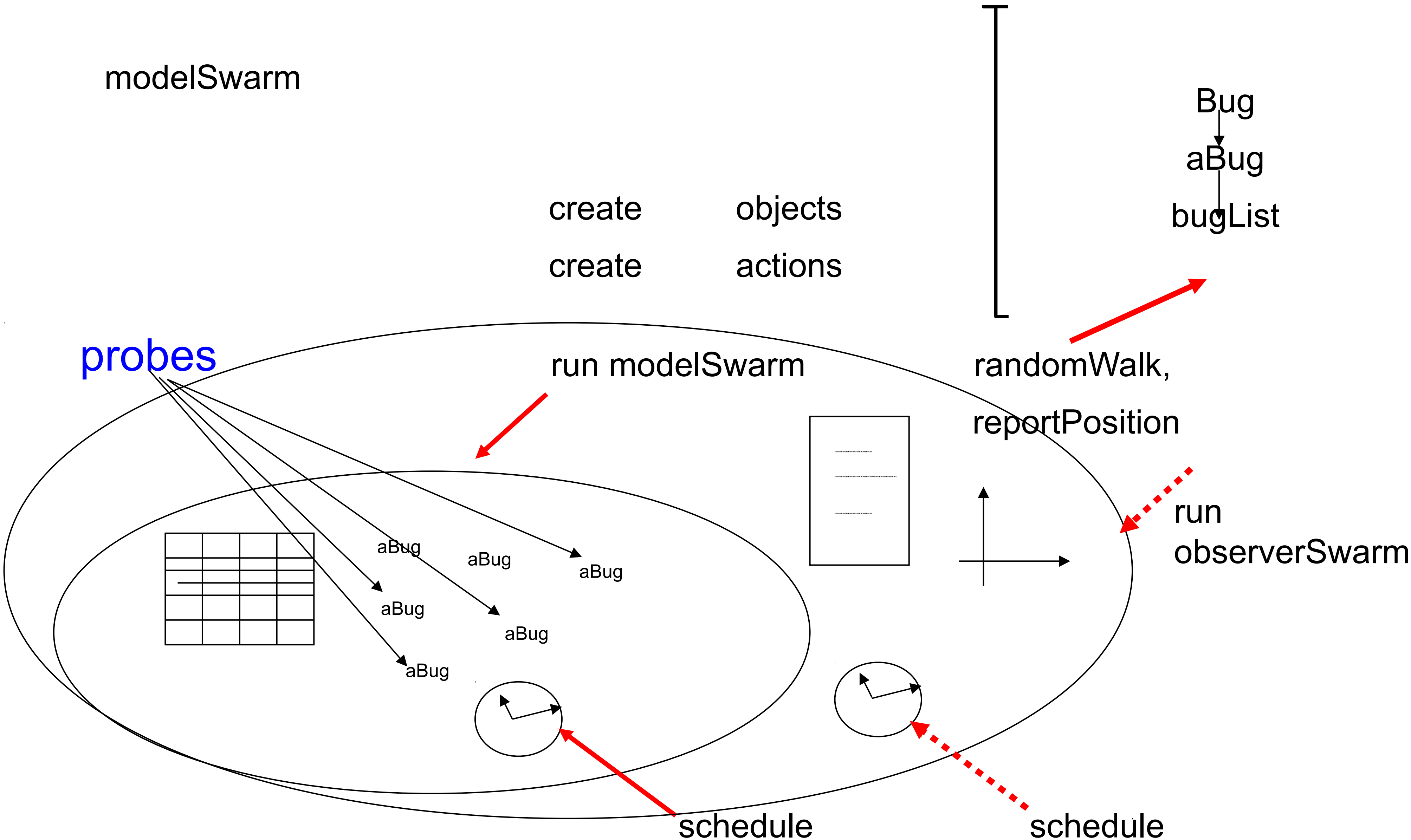


schedule

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



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



… and why NetLogo?

NetLogo is introduced as a rigorous and easy tool, mainly useful for prototyping and when we need advanced graphical capabilities

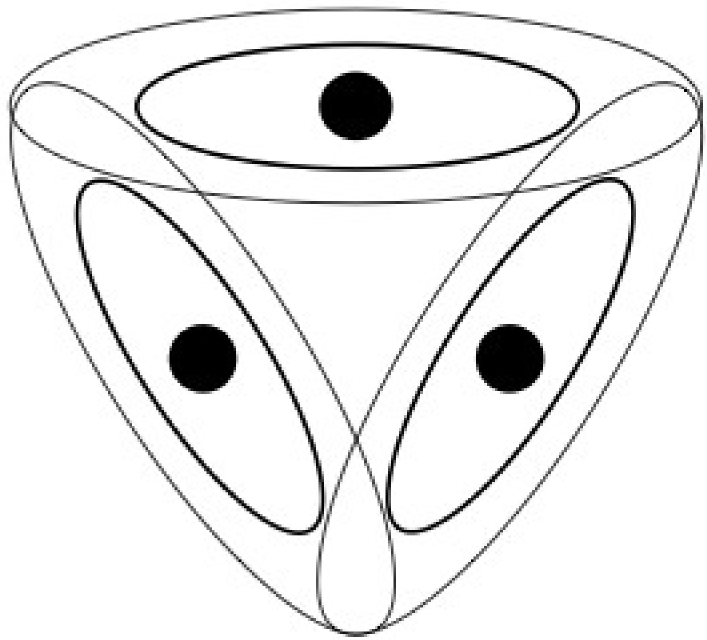
Limits are in coping with the design of complex experiments and with huge numbers of agents

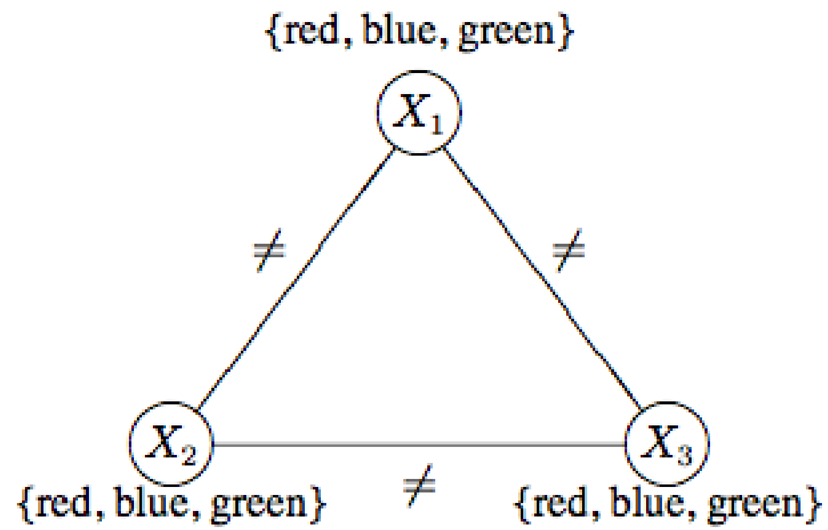
Technicalities II

ABM or MAS (Agent-Based Models or Multi-Agent Systems)?

Shoham, Y. and Leyton-Brown, K., 2008, Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Cambridge University Press

(p.230, v. on line) "There are other large-population models that provide a more fine-grained model of the process, with many parameters that can impact the dynamics. We call such models, which **explicitly model the individual agents, agent-based simulation models**."

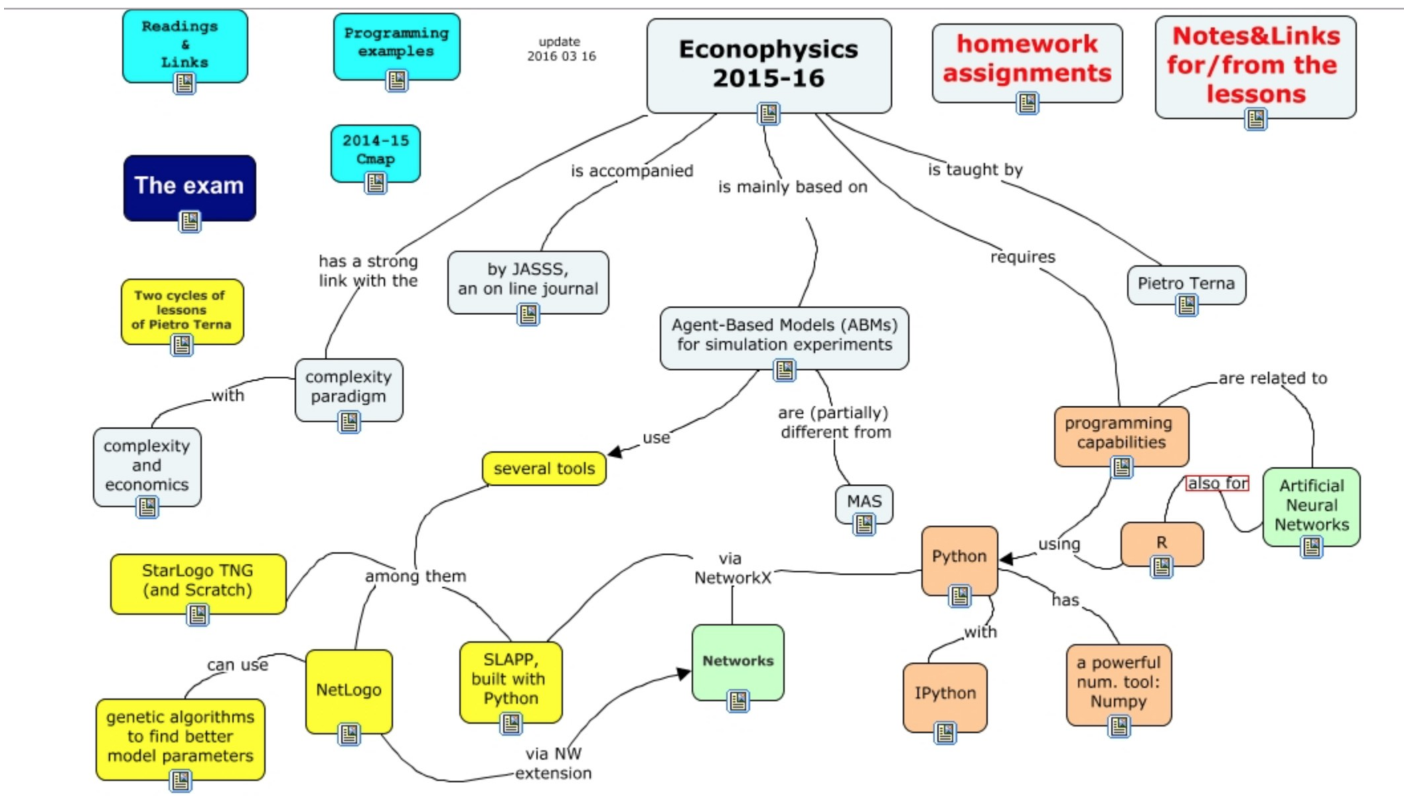




procedure Revise(x_i, x_j)
forall $v_i \in D_i$ **do**
  if *there is no value* $v_j \in D_j$ *such that* v_i *is consistent with* v_j **then**
    delete v_i from D_i

To search for agent-based related material look also at the *Conceptual Map* of my course of **Econophysics**
(Master degree in Physics of Complex Systems)

http://terna.to.it/econophysics16/cmap/Econophysics_2015_16.html



Have a look to:

Python

NetLogo