NETLOGO

SOFTWARE RAPID PROTOTYPING , MODELING OF PHYSICAL, CHEMICAL AND ENGINEERING

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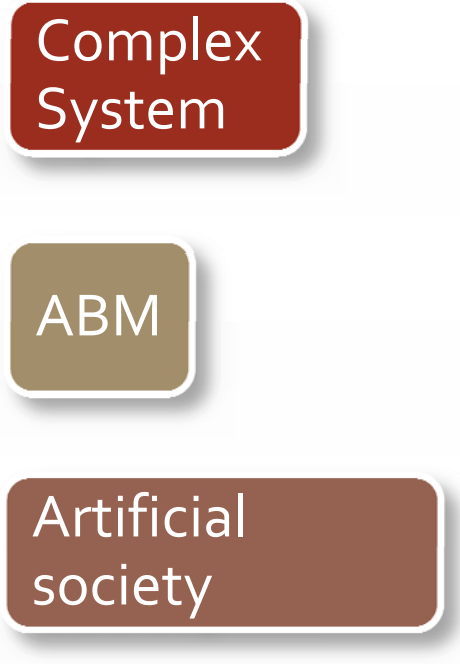
Netlogo ABM

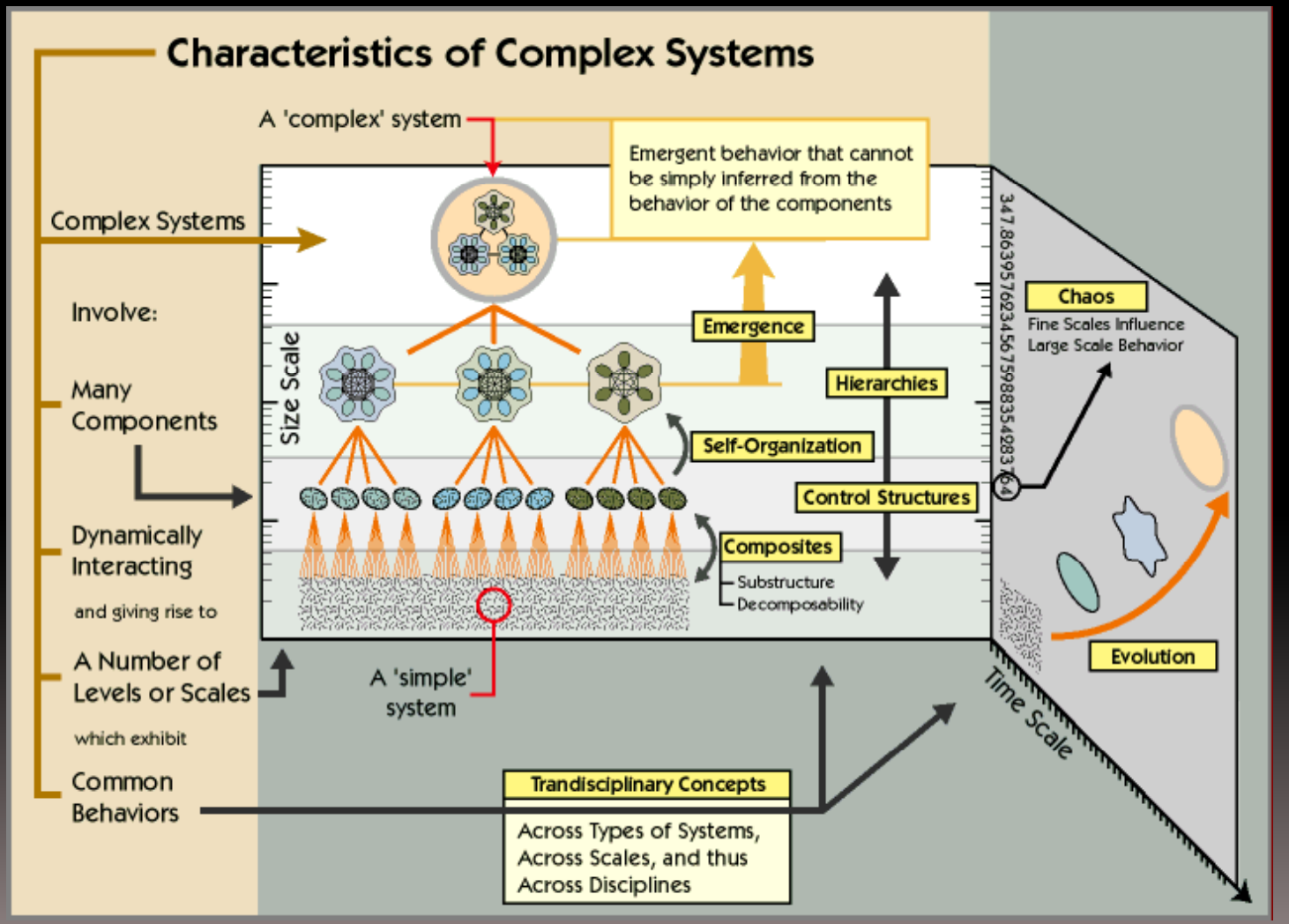
What is NetLogo?

- Modeling complex systems
- The world of NetLogo
  - Graphical interface
  - Programming concepts
- Tutorial: termites



Complex System

- A system is complex when it is composed of **many parts** that interconnect in **intricate ways**. (Joel Moses, "Complexity and Flexibility"). This definition has to do with the number and nature of the interconnections.
- A system presents **dynamic complexity** when **cause and effect are subtle**, over time. (Peter Senge, "The Fifth Discipline"). Egs: dramatically different effects in, the short-run and the long-run; dramatically different effects locally and in other parts of the system; obvious interventions produce non-obvious consequences.
- A system is complex when it is composed of a group of related units (subsystems), for which the **degree and nature of the relationships is imperfectly known**. (Joseph Sussman, "The New Transportation Faculty"). The overall **emergent behavior** is difficult to predict, even when subsystem behavior is readily predictable.


Characteristics of Complex Systems
A 'complex' system
Emergent behavior that cannot be simply inferred from the behavior of the components
Complex Systems
Involve:
Many Components
Dynamically Interacting
and giving rise to
A Number of Levels or Scales
which exhibit
Common Behaviors
Size Scale
Emergence
Hierarchies
Self-Organization
Control Structures
Composites
Substructure
Decomposability
A 'simple' system
Chaos
Fine Scales Influence Large Scale Behavior
Evolution
Time Scale
Trandisciplinary Concepts
Across Types of Systems, Across Scales, and thus Across Disciplines

- Implications of this definition:
  - A complex system is **non-fragmentable**.
  - A complex system comprises **real components that are distinct from its parts**
  - Complex systems have models, analytic or synthetic. But the **tools differ**

Applications

- Complexity Theory appears in many fields:
  - Economy, biology, society, ethology
- Other examples include
  - **Transportation Systems**
    - Transport systems are complex networks, internally interconnected at different scales
    - The system is stochastic by nature and policy-makers introduce strategies that affect the overall behavior of the system
  - **Dynamic Markets and Firms**
    - The market is ever changing, defined by firm interaction
    - Inside the firm: make boundaries permeable, allow the bottom-up flow of ideas, give up of the idea of equilibrium

Institutions

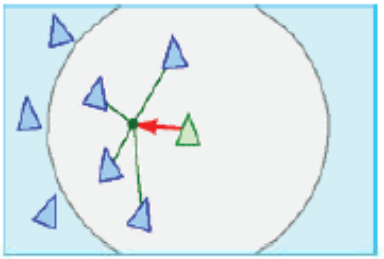
- Santa Fe Institute
  - Private, non-profit, multidisciplinary research and education center, founded in 1984
  - Largely Supported by the NSF and MacArthur Foundation
  - Operates as a small visiting institution
  - Catalyzes new collaborative, multidisciplinary projects
  - Primarily devoted to Basic Research
  - Gathers about 100 members, 35 in residence at one time

ABM

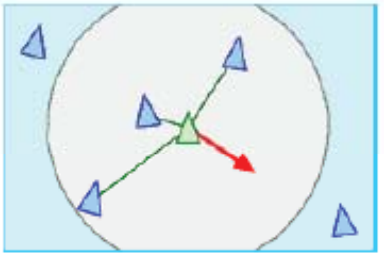
Agent-based Simulation Is a New Field Grounded in the Biological, Social, and Other Sciences

- What is an agent?
  - A discrete entity with its own goals and behaviors
  - Autonomous, with a capability to adapt and modify its behaviors
- Assumptions
  - Some key aspect of behaviors can be described.
  - Mechanisms by which agents interact can be described.
  - Complex social processes and a system can be built "from the bottom up."
- Examples
  - People, groups, organizations
  - Social insects, swarms
  - Robots, systems of collaborating robots
- Agents are diverse and heterogeneous

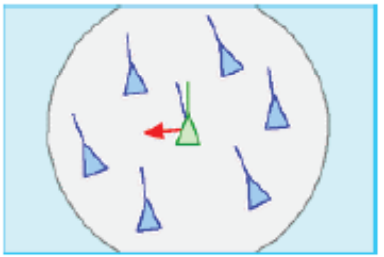
Example: Modeling Simple Schooling/Flocking Behavior with Agent Rules



Cohesion:
Steer to move toward the average position of local flockmates



Separation:
Steer to avoid crowding local flockmates



Alignment:
Steer towards the average heading of local flockmates

Source: "Boids" by Craig Reynolds, http://www.red3d.com/cwr/boids/

What Is An Agent? Agents Are Autonomous Decision-making Units with Diverse Characteristics (Heterogeneous)

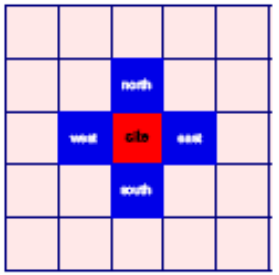
- **Decision rules vary by agent**
  - Sophistication of rules
  - Cognitive "load"
  - Internal models of the external world
  - Memory employed
- **Agents vary by their attributes and available accumulated resources**
- **What is the effect of agent diversity on the system?**
  - Do certain types of agents dominate?
  - Does the system evolve toward a stable mix of agent types?

Agent Interaction Topologies: Agents Have Neighborhoods

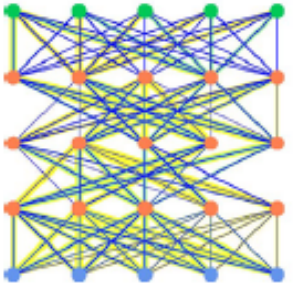
Various Topologies Connect Agents with Their Neighbors

- Agents can move in free (continuous) space
- Cellular automata have agents interacting in local "neighborhoods"
- Agents can be connected by networks of various types and be static or dynamic
- Agents can move over Geographical Information Systems (GIS) tilings
- Sometimes *spatial* interactions are not important ("Soup" Model)

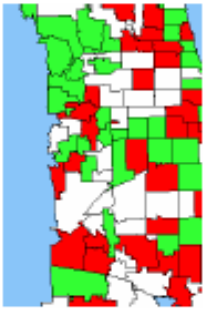
Euclidean Space: *2D, 3D*



Grid: *von Neumann neighborhood*



Network

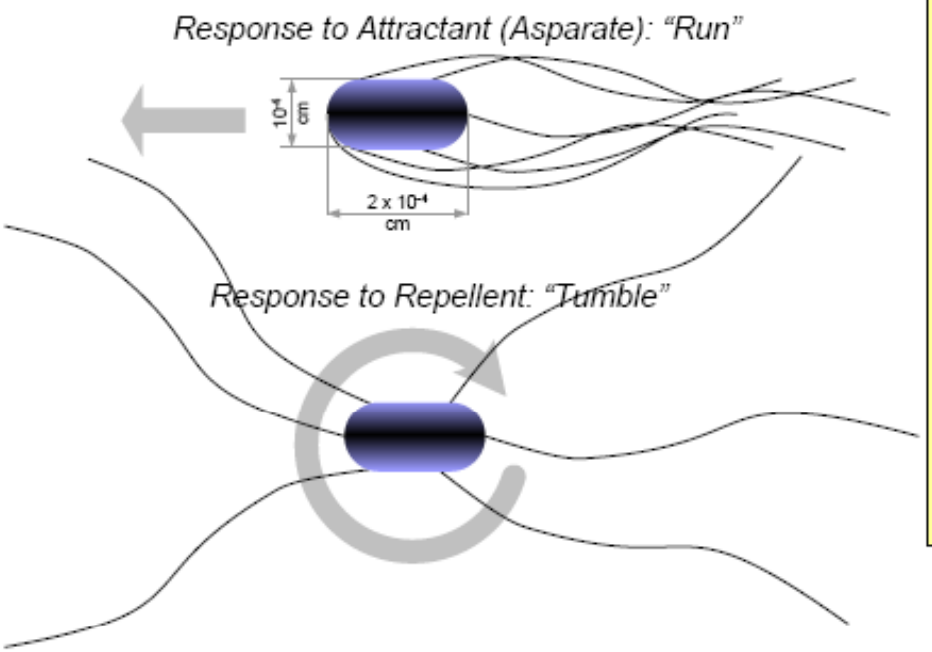


GIS: Geographic Information System

Application: Linking Chemical Reaction Networks to Behavior

Simulating bacterial chemotaxis allows us to understand the fundamental biochemical processes of all living things

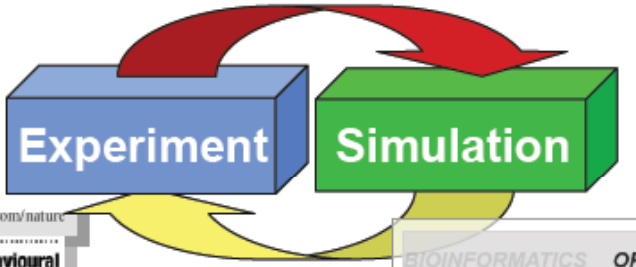
Motility of *Escherichia Coli*



Agent: Cell
- **Attributes:** Size
- **Rules of behavior:**
  - Natural motile behavior
  - Movement in response to stimuli
- **Memory: ???**
- **Sophistication:**
  - Interpret chemical signatures from other cells?
- **Resources: ???**

Agent-based Simulation Relates Characteristics of the Observed Behavior with Network Architecture

- First build an agent-based network that can reproduce some of the key properties of the chemotaxis network
- Validate model by comparing results of numerical simulations with lab data
- Use the flexibility of agent-based modeling to study the modular structure of the chemotaxis network and of signal transduction networks in general




NATURE | VOL 428 | 1 APRIL 2004 | www.nature.com/nature

From molecular noise to behavioural variability in a single bacterium


BIOINFORMATICS ORIGINAL PAPER

Systems biology

AgentCell: a digital single-cell assay for bacterial chemotaxis

Thierry Emonet[1,*], Charles M. Macal[2], Michael J. North[2], Charles E. Wickersham[1] and Philippe Cluzel[1]

[1]The Institute for Biophysical Dynamics and the James Franck Institute, The University of Chicago, 5640 S. Ellis

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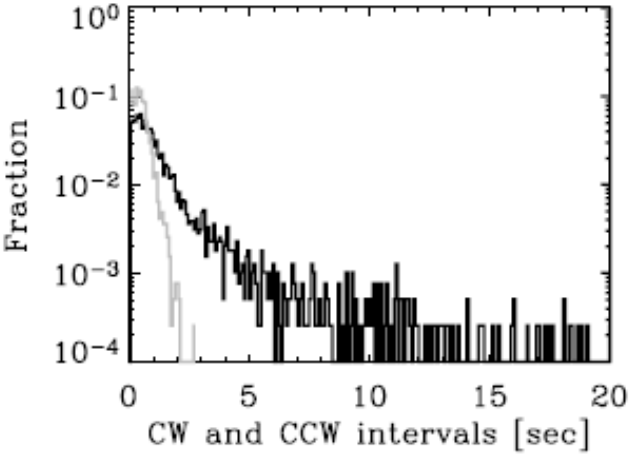
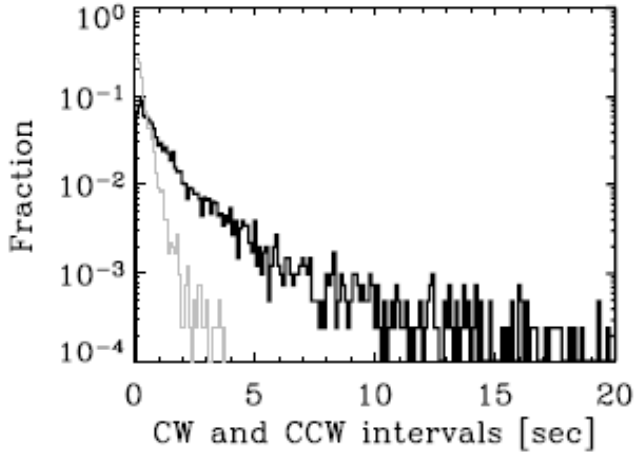
Center for Complex Adaptive Agent Systems Simulation (CAS2),
Decision & Information Sciences Division,
Argonne National Laboratory, Argonne, IL 60439 USA

Using AgentCell digital chemotaxis assays reproduce experimental data obtained from both single cells and bacterial populations.

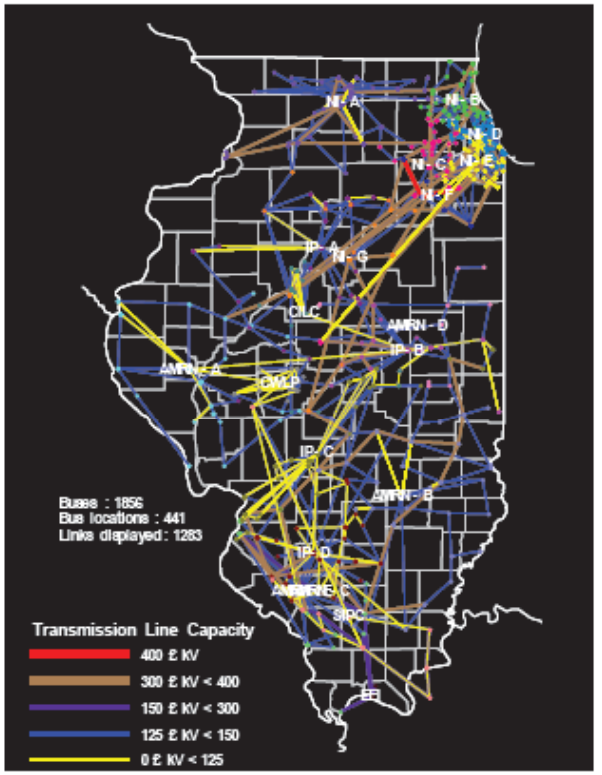
(a) ***experimental laboratory data*** on the distribution of CW (cell spins in place) and CCW (cell runs in a direction) intervals obtained by monitoring the switching events of individual cell flagella motors.



(b) ***simulated cell data*** on distribution of CW and CCW intervals resulting from the states of the motor in one of the cells in our digital population.

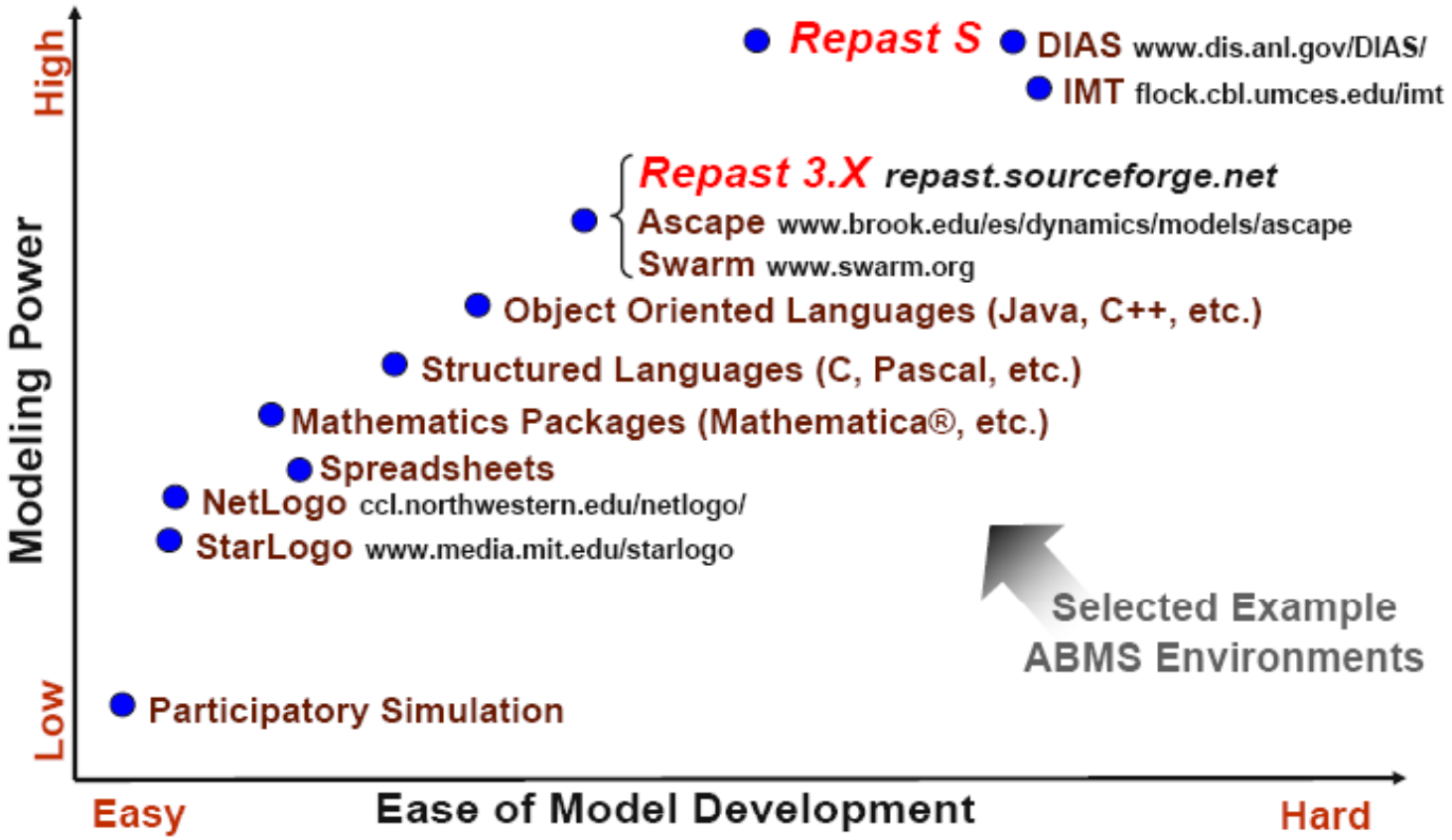


Large-Scale ABMS:
Application: Electric Power Markets
How will Illinois fare under electricity deregulation: Jan. 1, 2007?



- Will power transmission capacity be adequate, or is congestion likely? Under what conditions?
- Will transmissions constraints on the power grid create regional imbalances in supply and demand?
- Will imbalances create pockets of market power and potentially drive up locational electricity prices?

ABMS Uses Specific Tools



So, … what's NetLogo?

programmable modeling environment for simulating natural and social phenomena

well suited for modeling complex systems evolving over time hundreds or thousands of independent agents operating concurrently

exploring the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals

WHAT IS NETLOGO?

Inside Netlogo

Easy-to-use application development environment

opening simulations and playing with them

creating custom models: quickly testing hypotheses about self-organized systems

models library: large collection of pre-written simulations in natural and social sciences that can be used and modified

simple scripting language

user-friendly graphical interface.

Start Netlogo

WolfSheep

Segregation

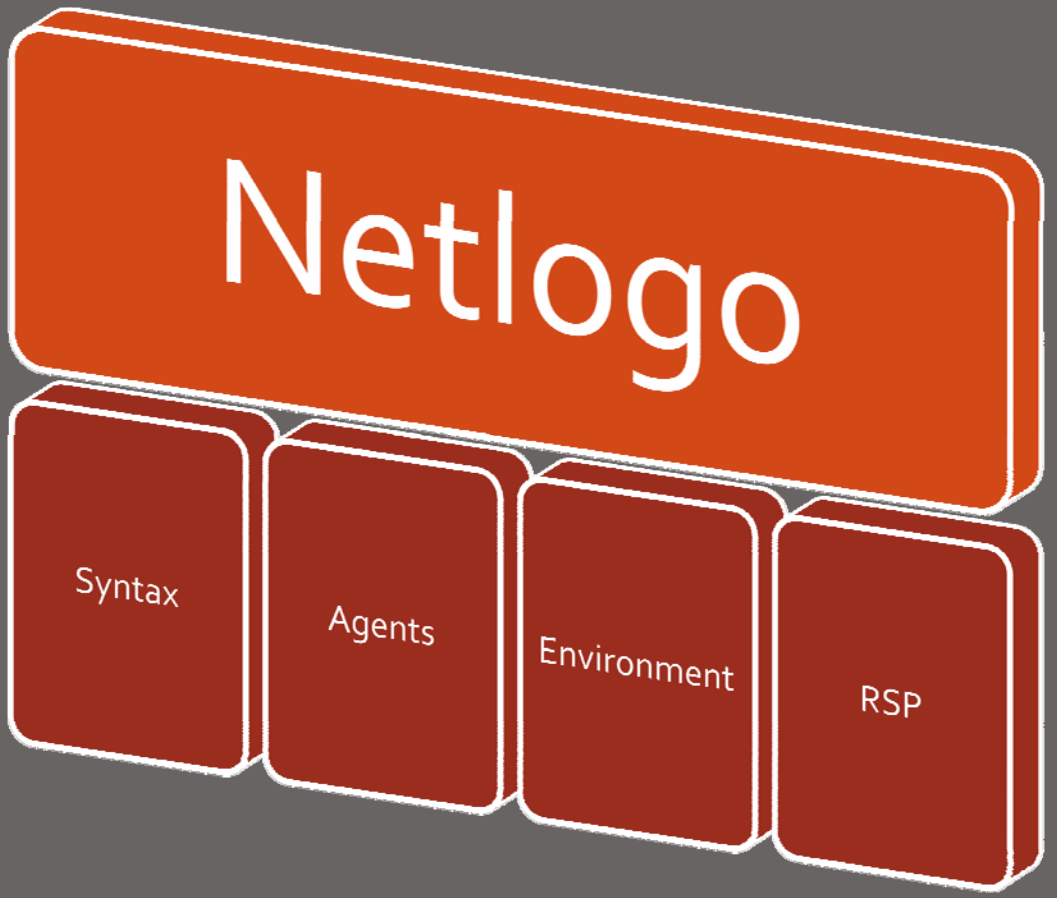
HeatBugs

GiantComponent

~~Rebellion~~

Other applications …

- **Radical polymerization**
- Turbolence
- Wave
- Network

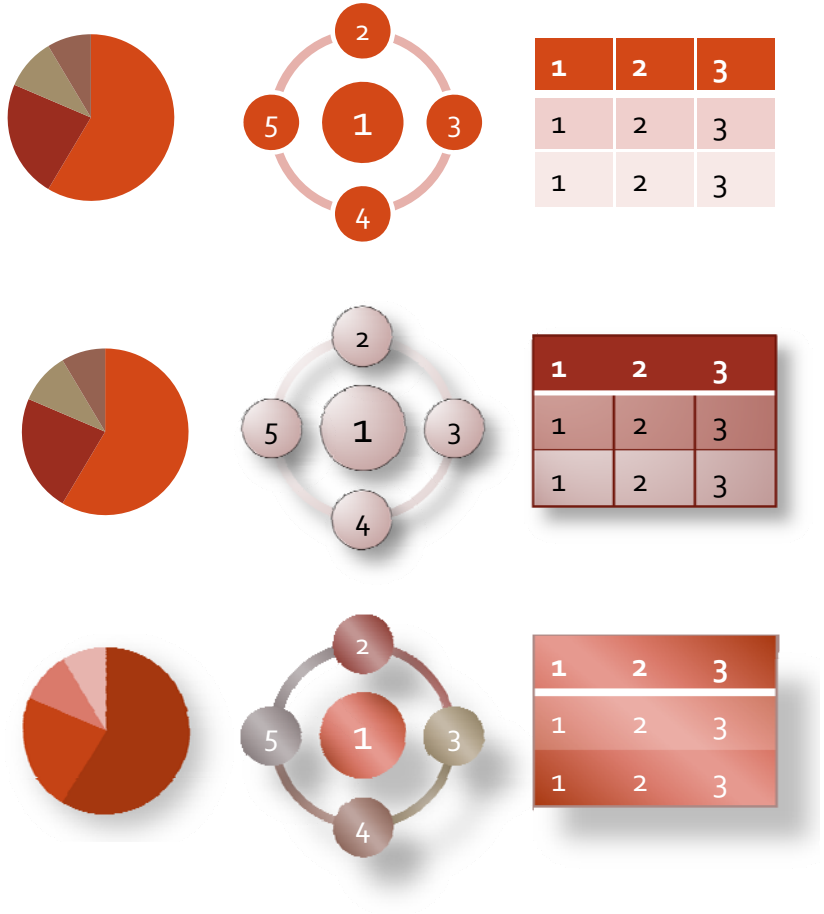

Netlogo
Syntax
Agents
Environment
RSP

… some side effects …

Small Know-How

… Reporting

….Visual Interface



Forward …

Java Extensions …

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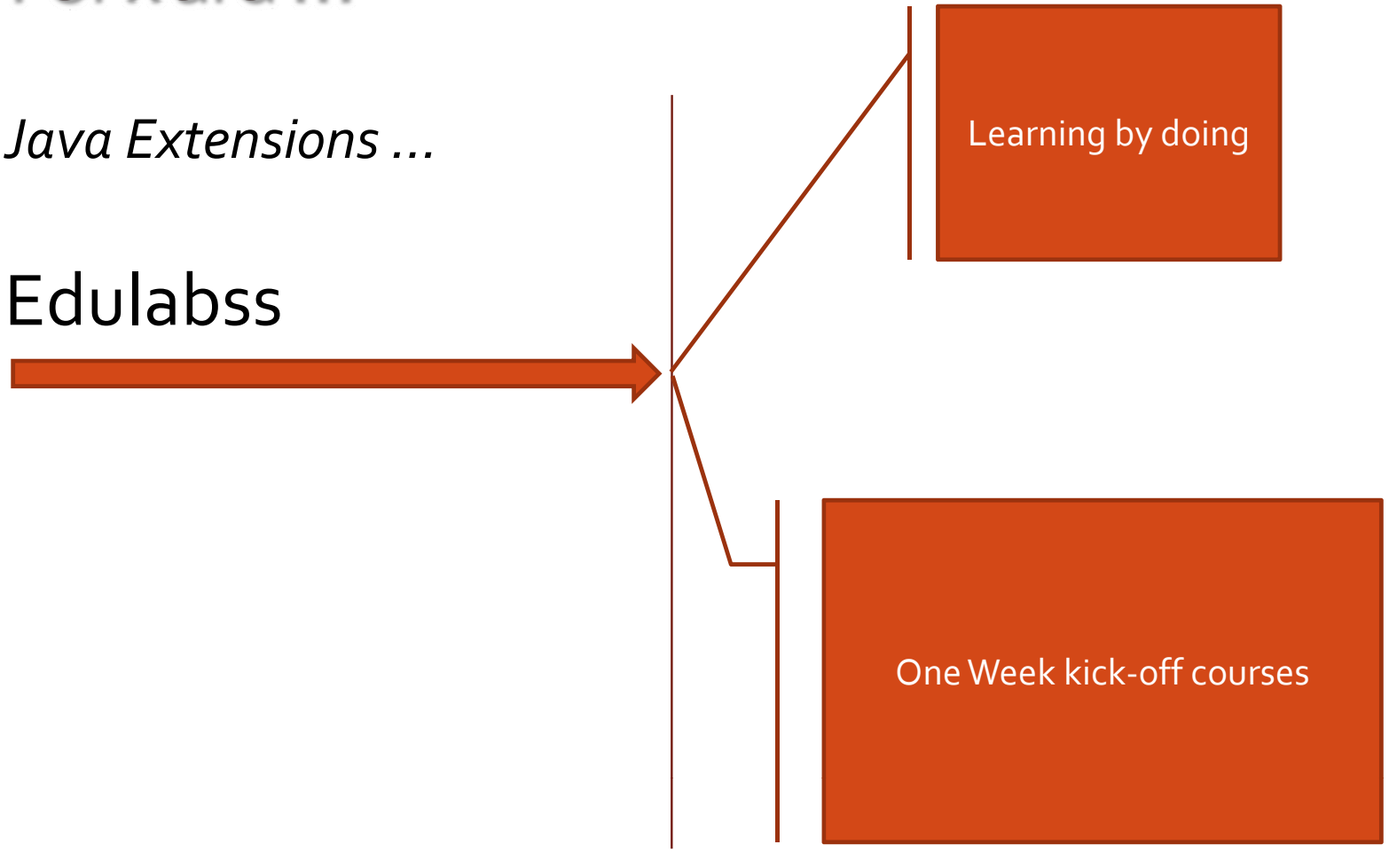

Thanks

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