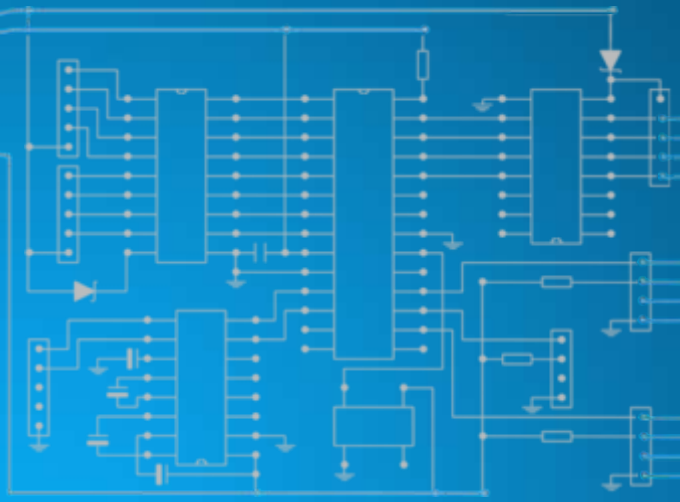
Agent Based Modeling and Simulation

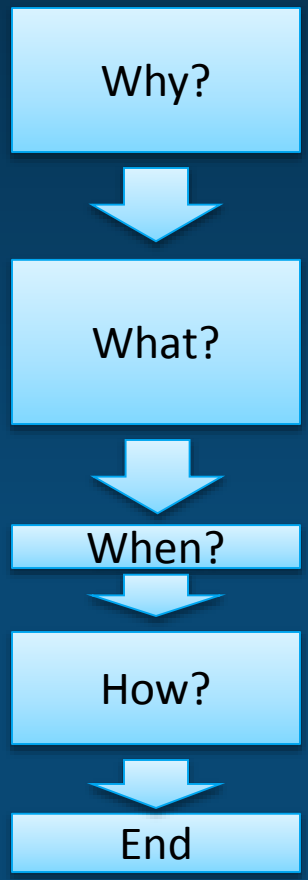
Overview and Tools



By Stathis Grigoropoulos

cropdesign
A BASF Plant Science Company

Agenda



Agent Based Modeling and Simulation Importance
- A Problem…
- Complex Adaptive Systems
- CAS Examples
- Simulation

Agent Based Simulation Definitions
- ABMS Characteristics
- ABMS Components
- Agent Definition
- Agent Environments
- Agent Interactions
- ABMS Examples

ABMS Usage

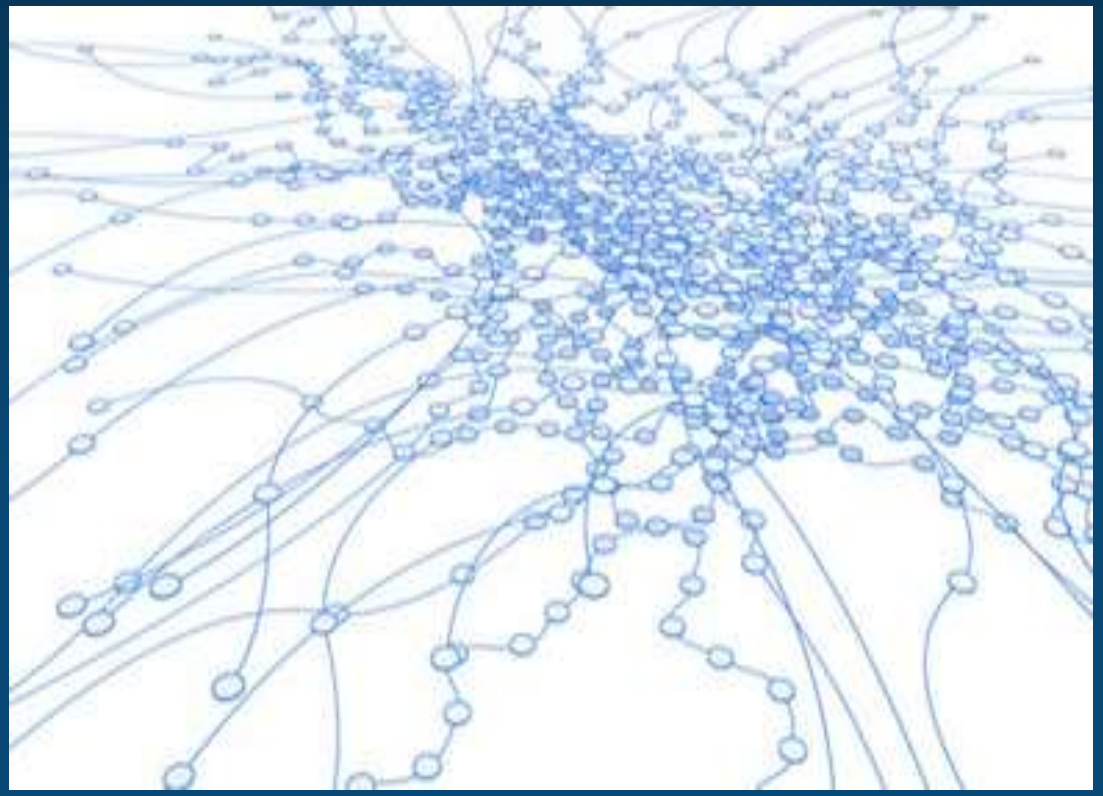
ABMS Software Tools
- The Big Two…
- NetLogo
- RePast

Summary – Q & A

Why? A Problem…

Problem:

Internet Service Provider (ISP) wants to increase the efficiency of the internet service by optimizing packet traffic over the routing network. However, the network looks like this

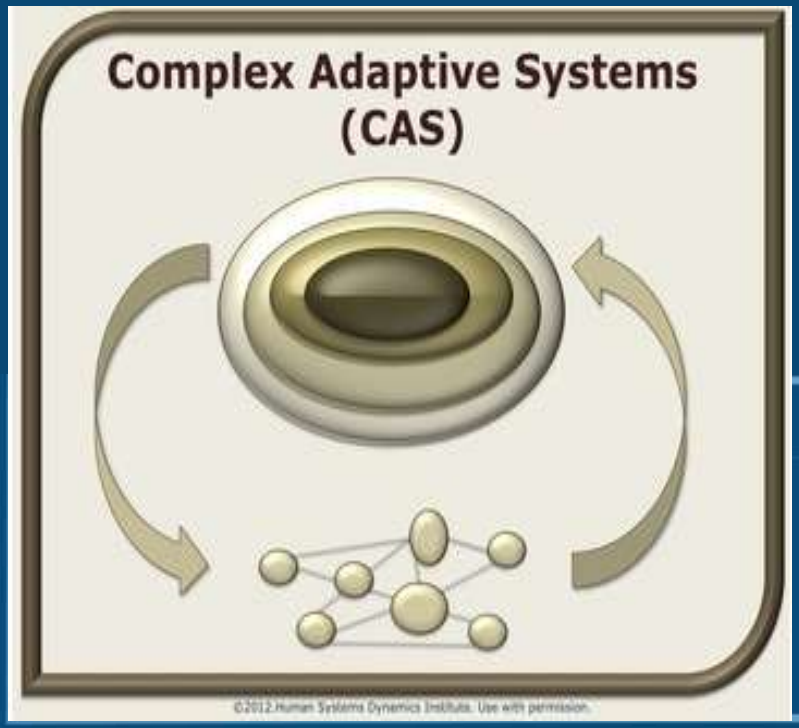


How do you model a Complex Structure?

Why? Complex Adaptive Systems

Answer:

Agent Based Paradigm can help analyze and simulate Complex Adaptive Systems (CAS).



Definition(s) of CAS?

- A complex system is one in which there are *multiple interactions between many different components*
- A complex system is a *highly structured* system, which shows *structure with variations…*

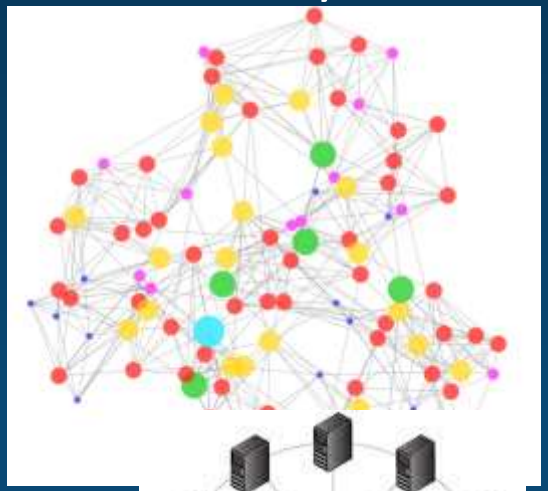
Features of CAS:

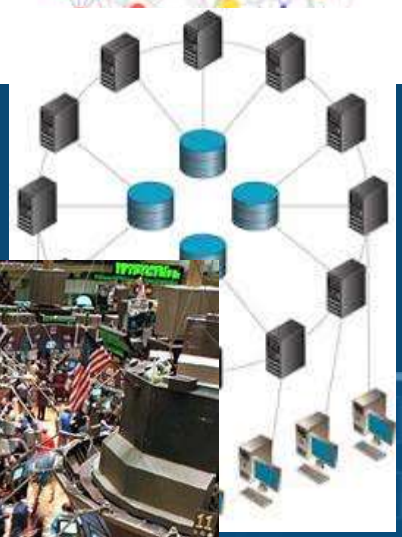
- Composed by several interacting elements
- Nonlinearity
- Networked structure
- Hierarchical structure
- Possibility to evolve and adapt …

Why? CAS Examples

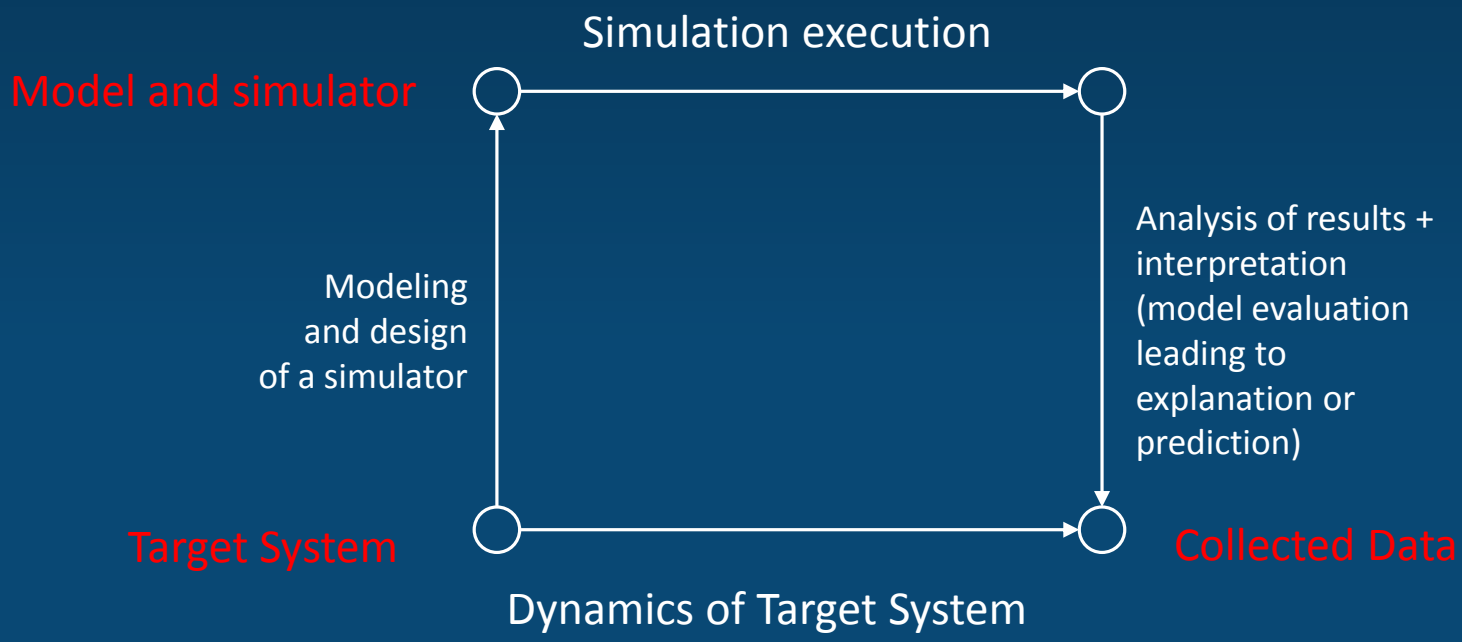
Examples of CAS using ABMS (non exhaustive)

- Biology
  - Virus Spreading
  - Population Dynamics
- Technology
  - Distributed and Parallel Systems
  - Wireless and Sensor Systems
- Finance & Business
  - Modeling Markets
  - Workforce Management
- My Msc Thesis





Why? Simulation

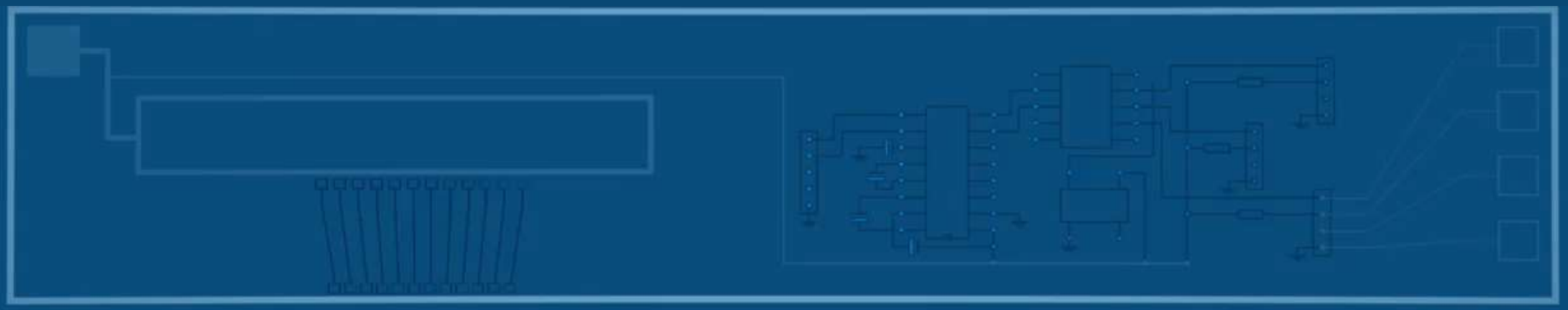


What? ABMS Characteristics

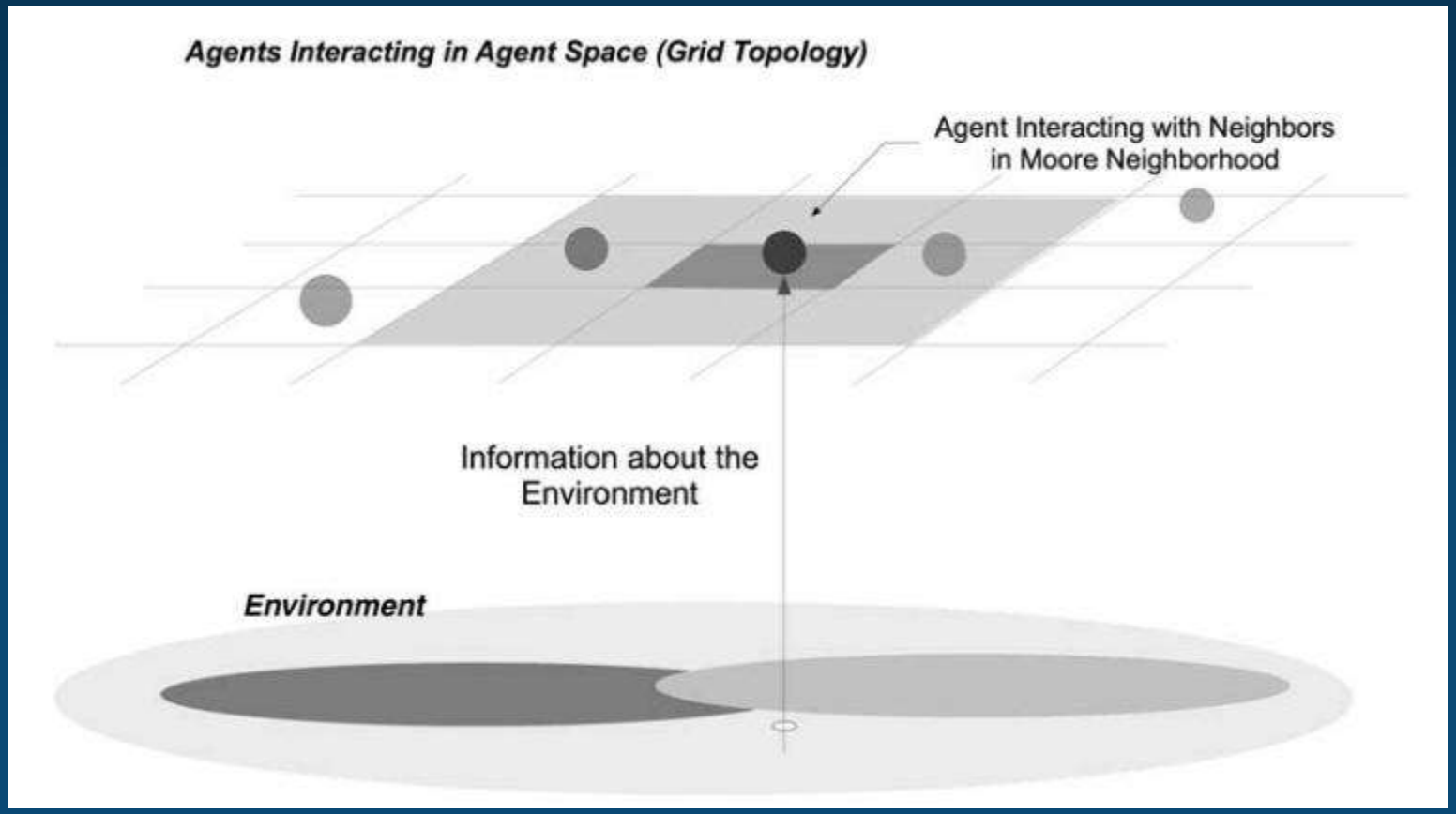
- Agent Based Modeling and Simulation (ABMS) is a new approach to modeling systems comprised of autonomous, interacting Agents.
- ABMS is a bottom-up process.
- Emergent phenomena from micro-behavior.
- Describes both optimization models and investigation of a dynamic process.
- ABMS succeeds where centralized planning and optimization models fail.

What? ABMS Components

- A set of agents, their attributes and behaviors.
- A set of agent relationships and methods of interaction:
  - An underlying topology of connectedness defines how and with whom agents interact.
- The agents' environment:
  - Agents interact with their environment in addition to other agents



What? ABMS Components



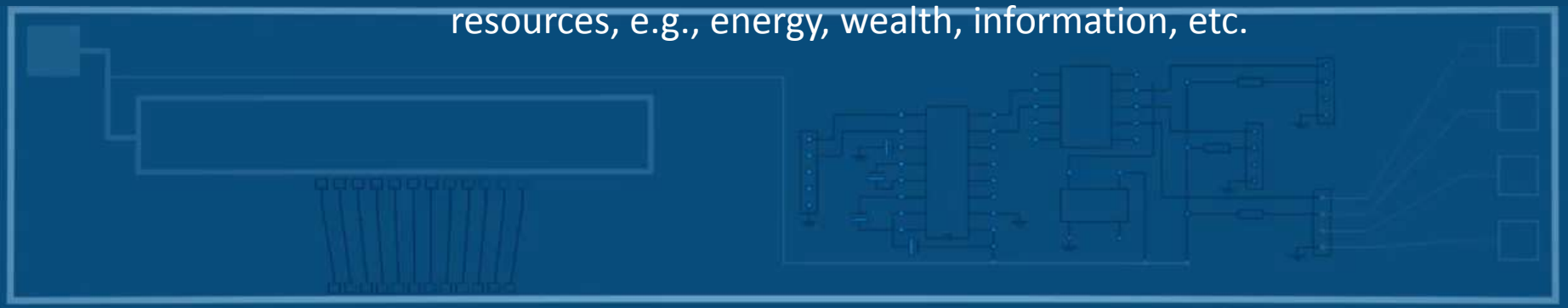
A schematic of Agent Components

What? Agent Definition

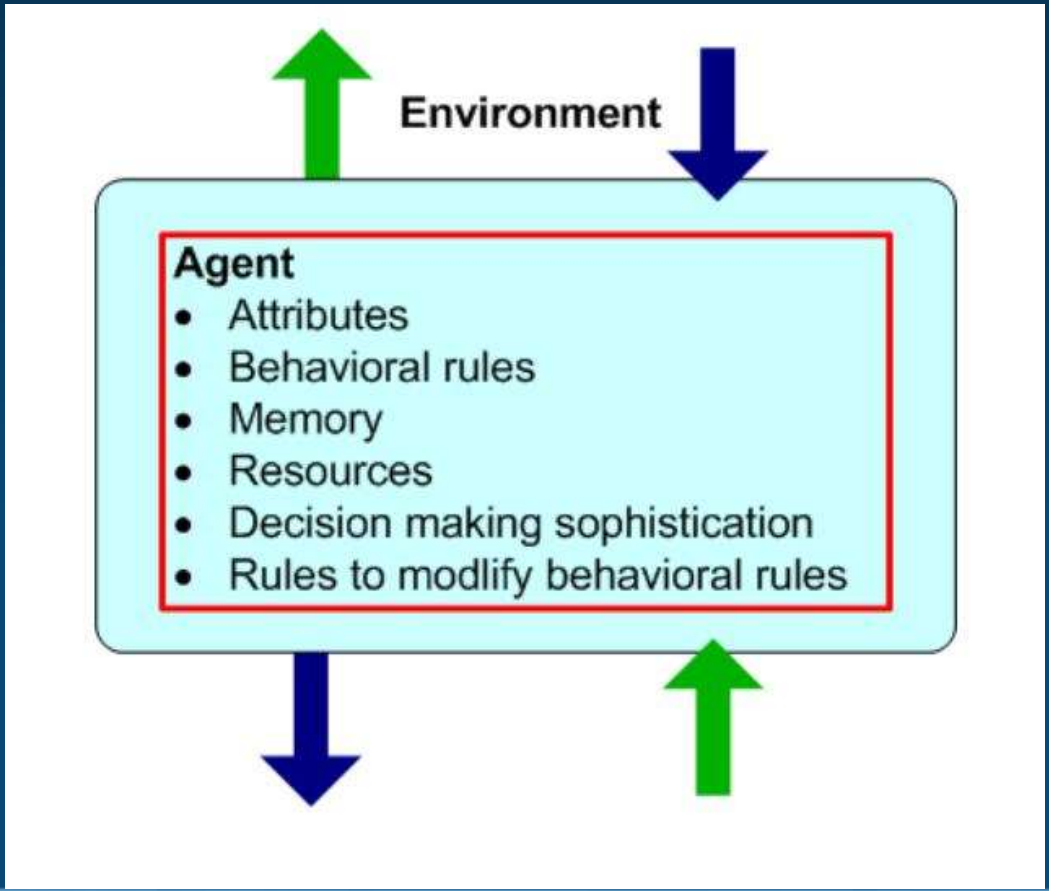
- There is no universal agreement on the precise definition of the term “agent” in the context of ABMS.
- We can however provide the main characteristics of an agent:
  - Autonomous:
    - Through agent and environment interaction, agent follows a behavior that relate information with action.
    - Simple rules to Neural Networks.
  - Self-contained:
    - Each agent is unique and modular.
    - One can distinguish whether a part of the model is a part of a specific agent or not.
  - Interacting with other agents:
    - Agents can be social.
    - Interact with other agents through protocols, e.g. movement in space, network connectivity.

What? Agent Definition

- In addition an agent may be:
  - Adaptive:
    - Able to modify a set of behaviors, adapt based on experience.
  - Goal-Directed:
    - Not necessary maximization.
    - Adapt behavior response to achieve goal.
  - Heterogeneous :
    - Unlike particle simulations, agent intelligence and behavior may vary in the same environment.
  - Equipped with Resources :
    - Resource attributes indicate its current stock of one or more resources, e.g., energy, wealth, information, etc.

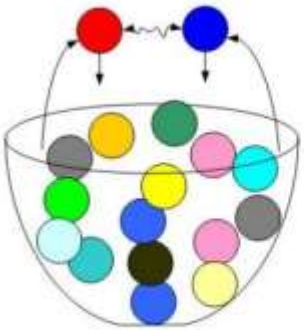


What? Agent Definition

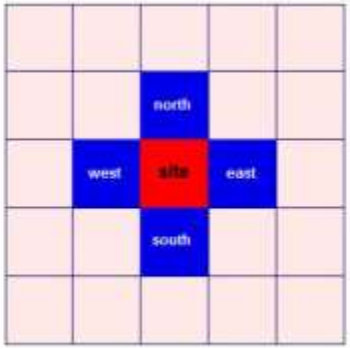


A typical Agent

What? Agent Environments

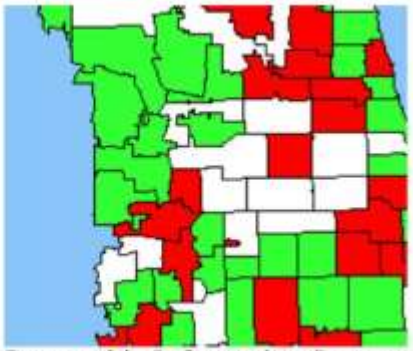


(a) "Soup" Model (Aspatial)

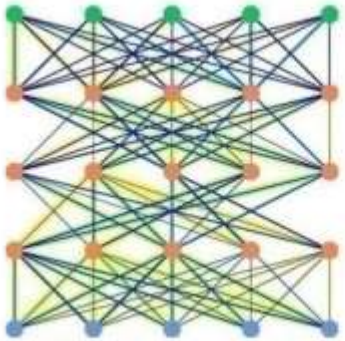


(b) Cellular Automata (von Neumann)

(c) Euclidean Space (2-D)



(d) Geographic Information System (GIS)

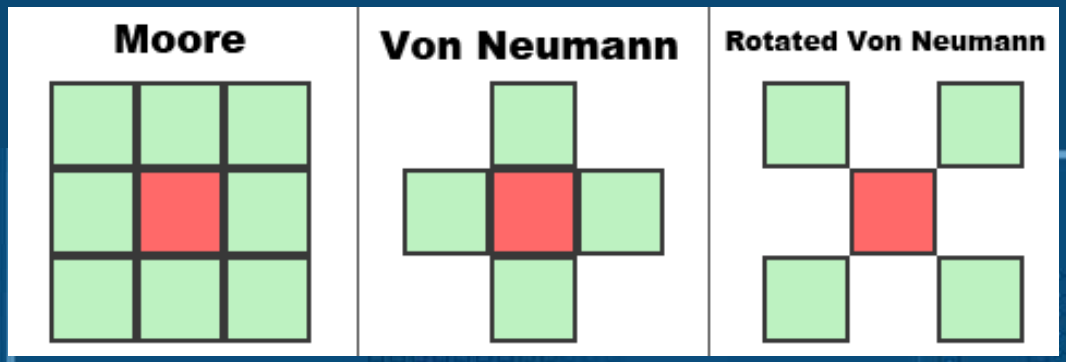


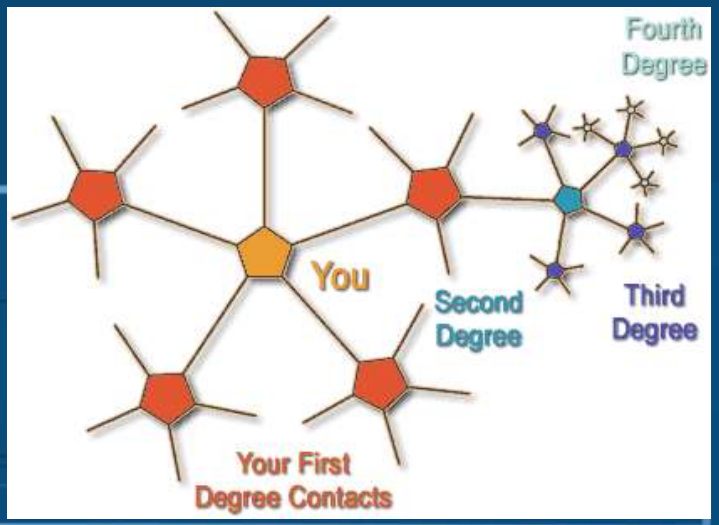
(e) Network topology

Types of Agent Environments

What? Agent Interactions

- Depending on the environment agents interact in a subset topology.
- Typically an agent interact with neighbors
- For example:
  - In a Grid, surrounding cells are the neighborhood.
  - In a network, the first degree connections are neighbors.





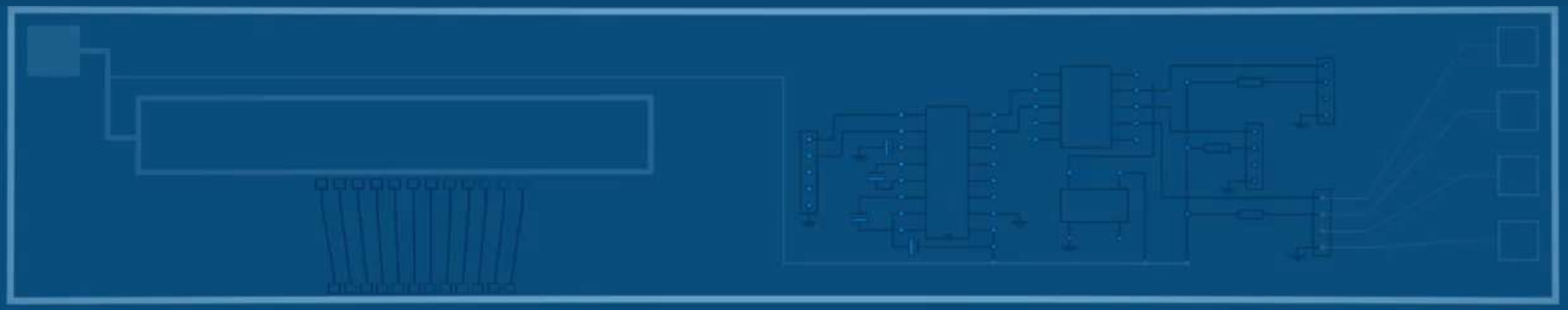
What? ABMS Example

Game Of Life:

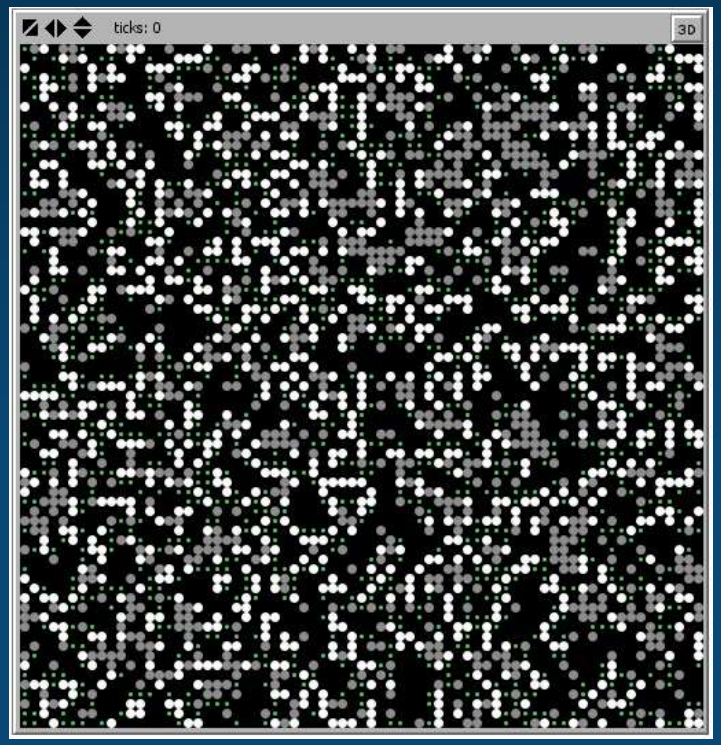
- two-dimensional orthogonal grid
- Agents are cells, state dead or alive

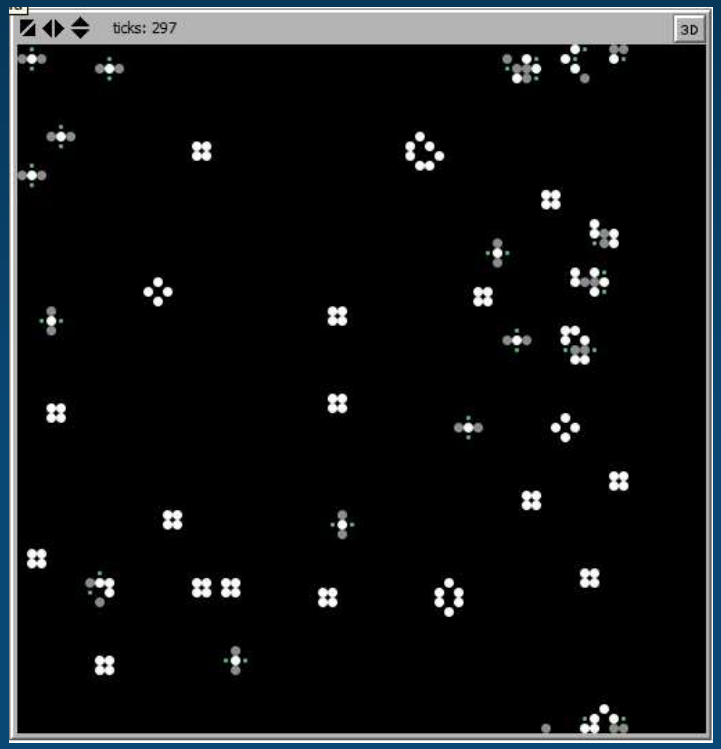
Rules:

- Any live cell with fewer than two live neighbors dies, as if caused by under-population.
- Any live cell with two or three live neighbors lives on to the next generation.
- Any live cell with more than three live neighbors dies, as if by overcrowding.
- Any dead cell with exactly three live neighbors becomes a live cell, as if by reproduction.



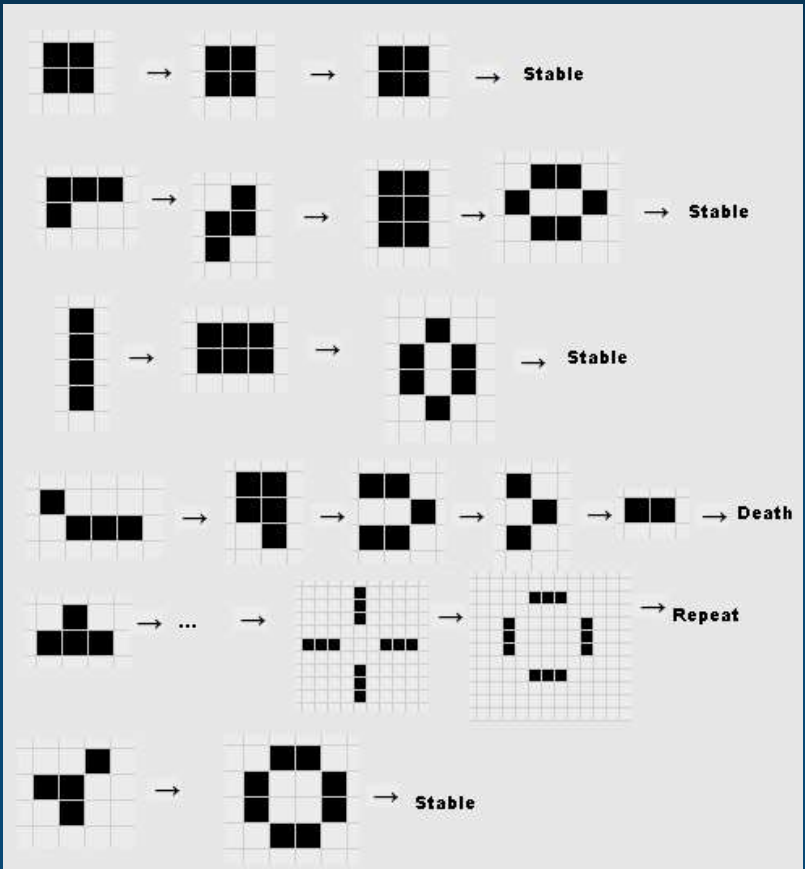
What? ABMS Example

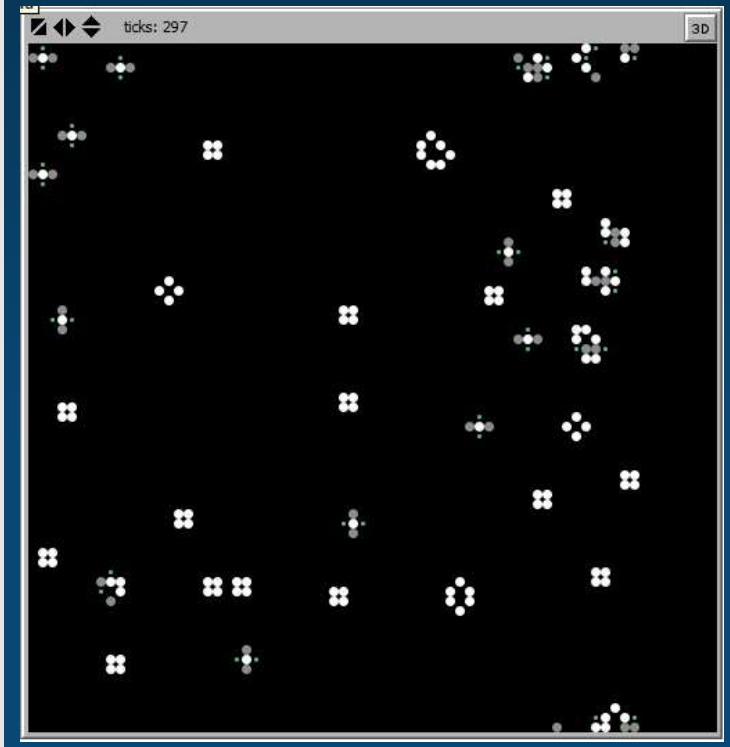




Game Of Life Initial and Steady State.
At the Steady State patterns are emerging.

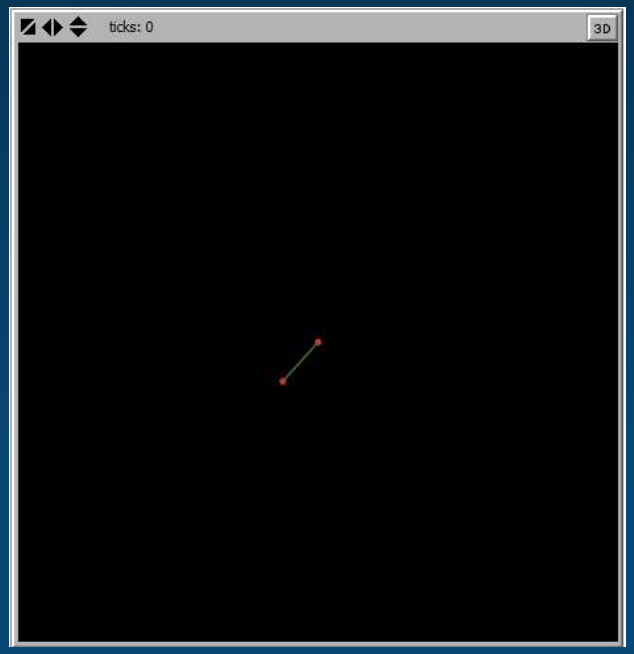
What? ABMS Example

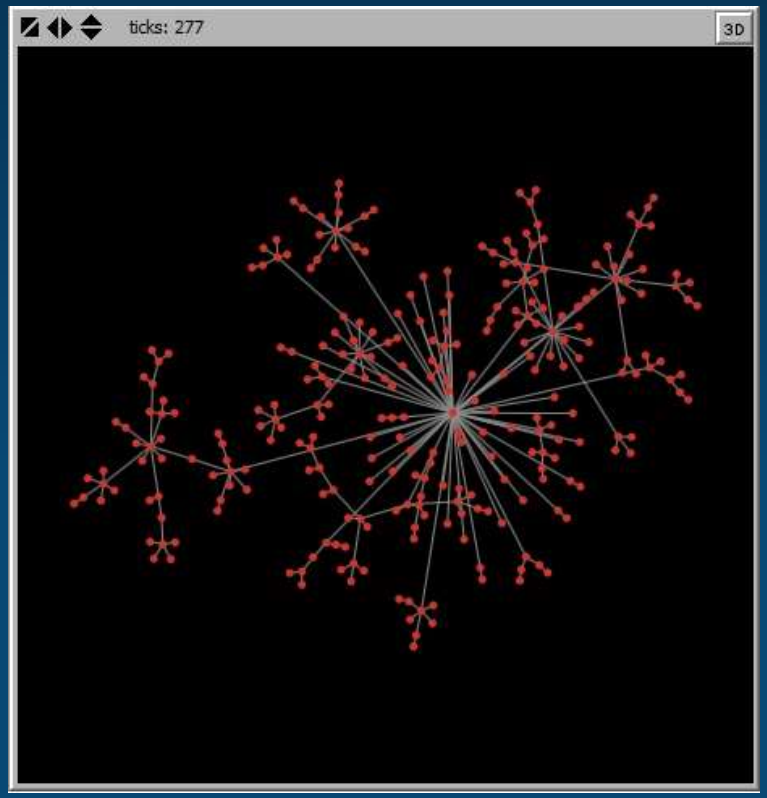




Game Of Life Steady State.
At the Steady State patterns are emerging.

What? ABMS Example



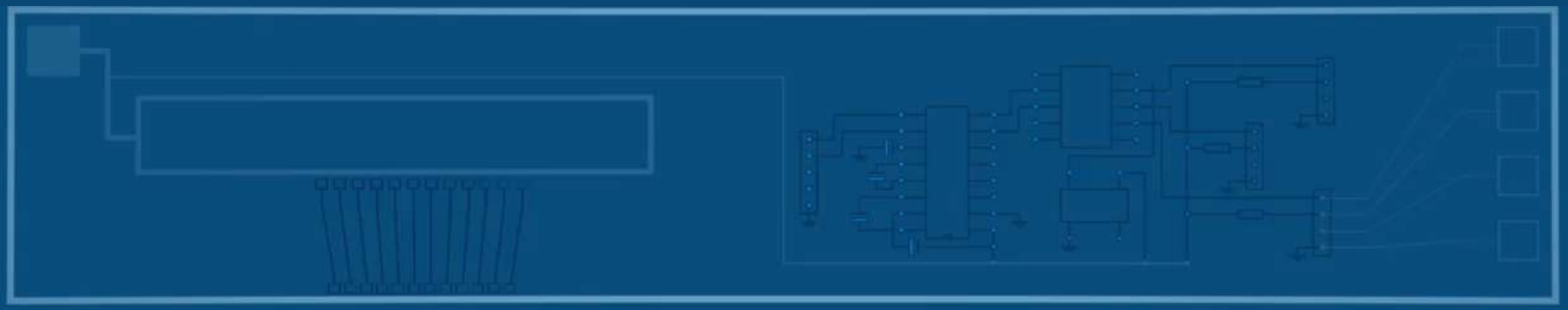


Preferential Attachment:

- The model starts with two nodes connected by an edge.
- At each step, a new node is added. A new node picks an existing node to connect to randomly, but with some bias
- Node's chance of being selected is directly proportional to the number of connections it already has.

When? ABMS Usage

- When there are decisions and behaviors that can be well-defined.
- When it is important that agents adapt and change their behaviors.
- When it is important that agents have a dynamic relationship with other agents, and agent relationships form, change and decay.
- When the past is no predictor of the future because the processes of growth and change are dynamic.
- When process structural change needs to be an endogenous result of the model, rather than an input to the model.



How? ABMS Software

- ABMS Software Packages
  - AgentSheets
  - AndroMeta
  - AnyLogic
  - Ascape
  - Breve
  - Cormas
  - DEVS: Discrete Event System Specification
  - EcoLab
  - FLAME: FLexible Agent Modelling Environment
  - JAS: Java Agent Based Simulation Library
  - LSD: Laboratory for Simulation Development
  - MAML: Multi-Agent Modelling Language
  - MATSim
  - MASON: Multi-Agent Simulation of Neighbourhoods
  - MASS: Multi-Agent Simulation Suite
  - MetaABM
  - MIMOSE
  - MobiDyc: Modélisation Basée sur les Individus pour la Dynamique des Communautés
  - Modelling4all
  - NetLogo
  - Open StarLogo
  - RePast: Recursive Porous Agent Simulation Toolkit
  - Repast Simphony
  - SimPack
  - SimPy
  - SOARS: Spot Oriented Agent Role Simulator
  - StarLogo
  - SugarScape
  - Swarm
  - VisualBots
  - Xholon

- Other Multi-Agent Systems
  - A-globe
  - ABLE: Agent Building and Learning Environment
  - Cougaar: Cognitive Agent Architecture
  - FIPA: Foundation for Physical Intelligent Agents
  - JADE: Java Agent Development Framework
  - Jason
  - MadKit
  - MAGSY
  - MASIF
  - SDML: Strictly Declarative Modelling Language
  - SeSAm: Shell for Simulated Agent Systems
  - SimAgent
  - Zeus

- ABMS on HPC
  - HPC Clusters
  - BlueGene
  - GPGPU
  - Cell

…Just a few ABMS Software Tools

How? The Big Two…

NetLogo

The Center for Connected Learning (CCL) and Computer-Based Modeling, Northwestern University, USA.

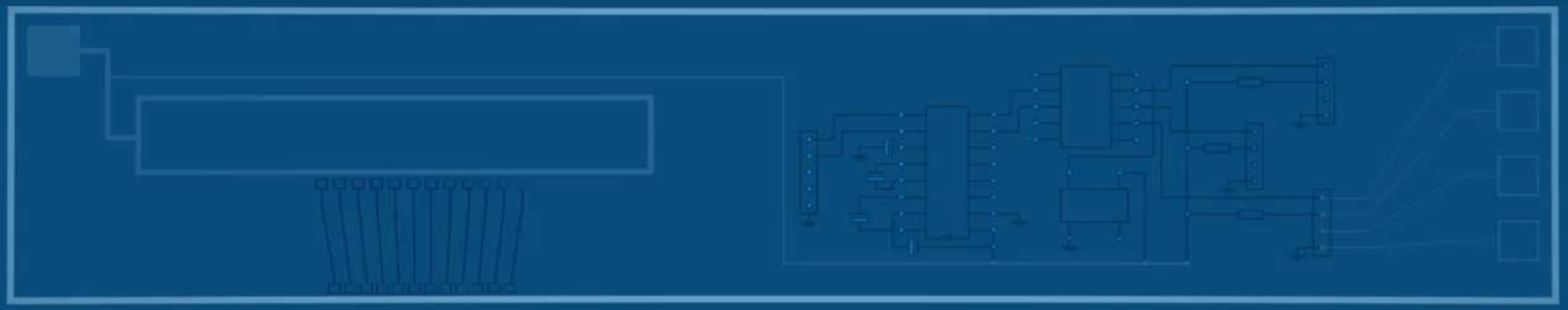
Both Free, Open Source

Repast Simphony

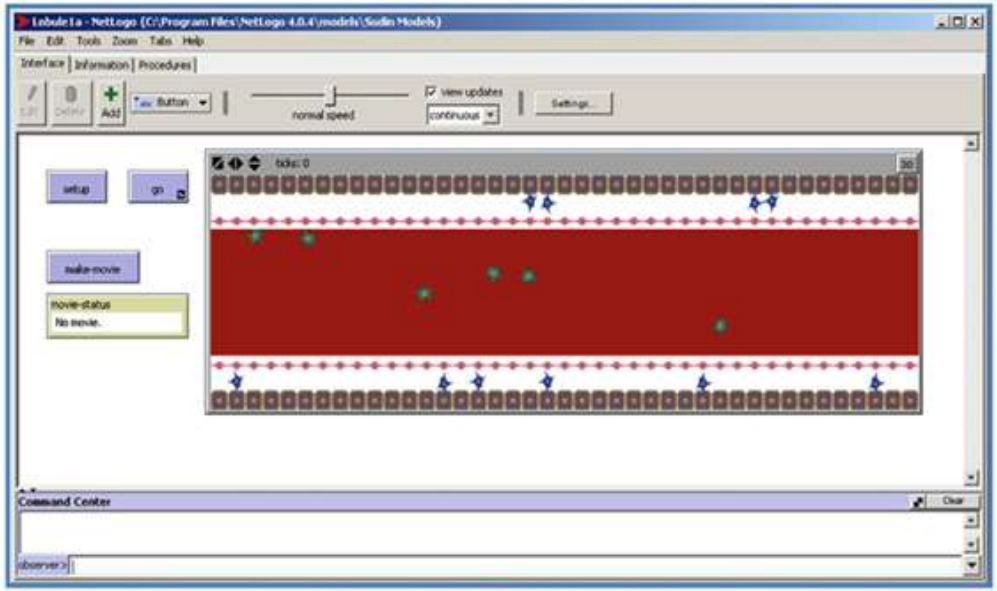
Argonne National Laboratory, Chicago, USA.

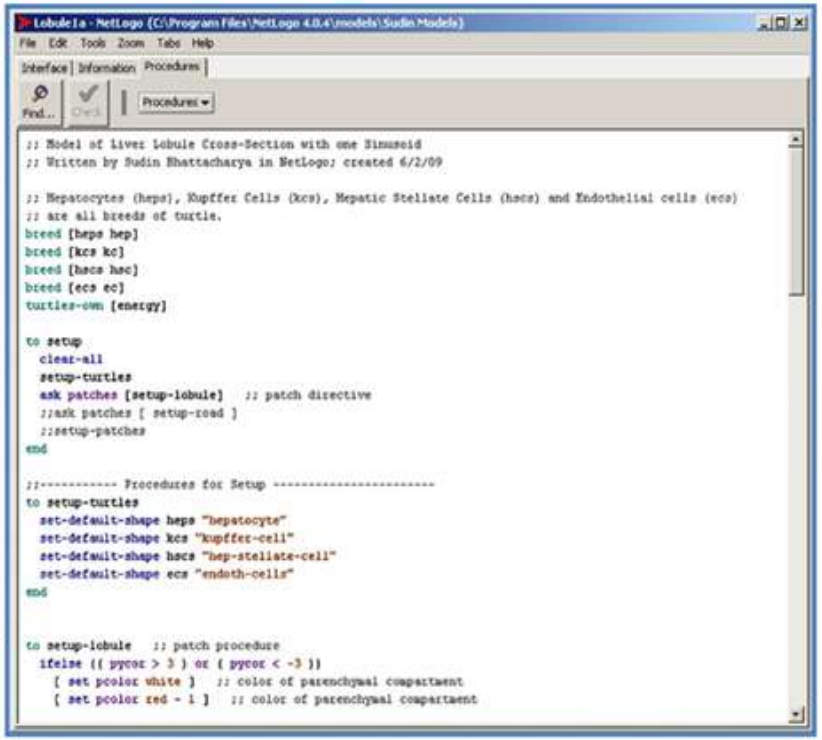
How? NetLogo

- The name NetLogo comes from “Network Logo” and is a functional programming language (Byproduct of Lisp).
- Java based Platform (build-in UI and programming interface).
- “Turtles” represent the agents and have some state (unique identity, position, and attributes).



How? NetLogo

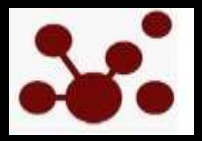




NetLogo User and Programming Interface

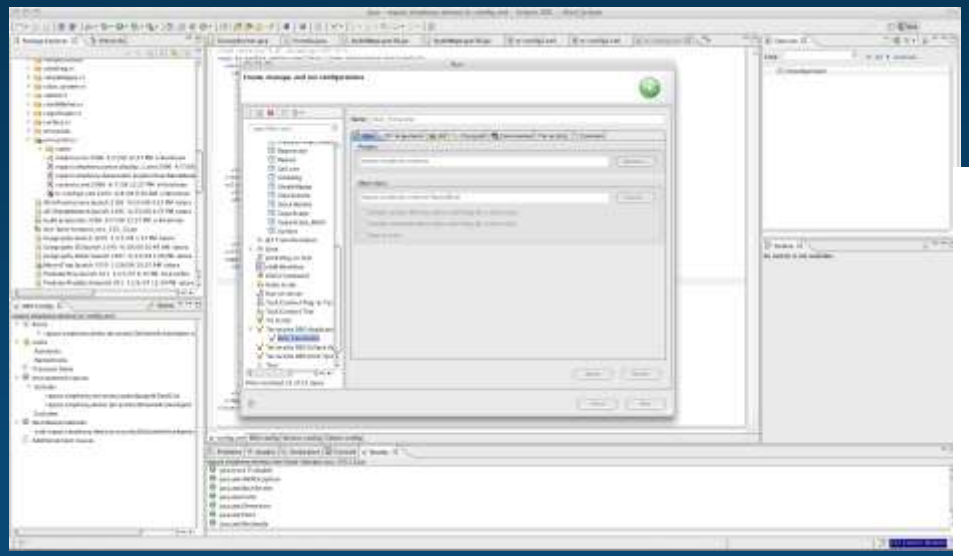
How?  NetLogo

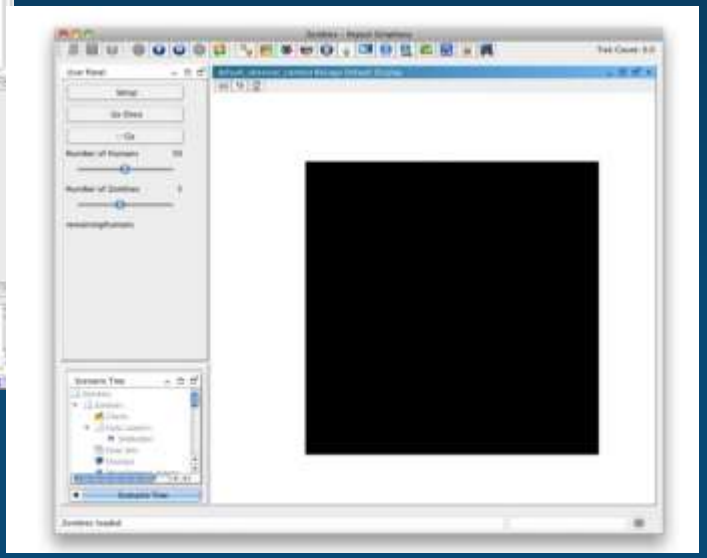
- Very popular tool (educational purpose).
- Easy-to-use language, great for beginners.
- Mature platform, rare bugs to none.
- Contains many useful already-made primitives and structures.
- Great for prototyping models, deploys web Java applets.
- Many example available.
- Great documentation, active community.
- Can be used for complex models also.
- Scalability issues.
- Becomes slow when things get complicated.
- Lack of Object Oriented style, debugger.

How?  Repast

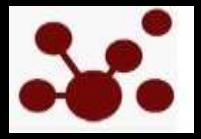
- Recursive Porous Agent Simulation Toolkit (RePast).
- Java based Framework and Library (ships with customized Eclipse IDE).
- Initial language used was Java, however seeing the success of NetLogo, ReLogo was introduced.

How? Repast





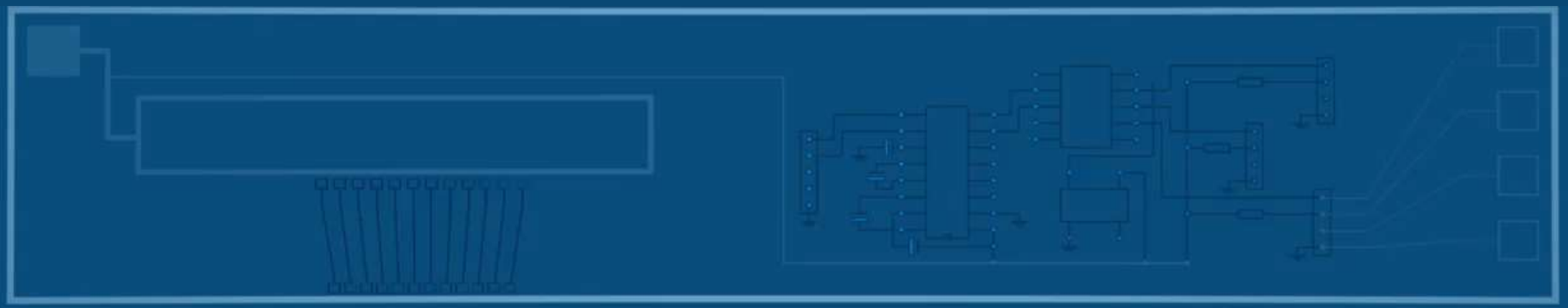
Repast View and Eclipse Programming Interface

How?  Repast

- \+ Popular tool (social sciences targeted).
- \+ Object Oriented and functional for tutoring.
- \+ Very good documentation, active community.
- \+ Usage of Eclipse.
- \+ Mature platform, some bugs.
- \+ Lots of examples available.
- \+ Includes 3D GIS using GeoTools, Imports NetLogo.
- \+ Scalable for complex models.
- − Learning curve, experience in Java regardless of examples.
- − No connection of ReLogo and Java.
- − Not so many primitives and structures available.

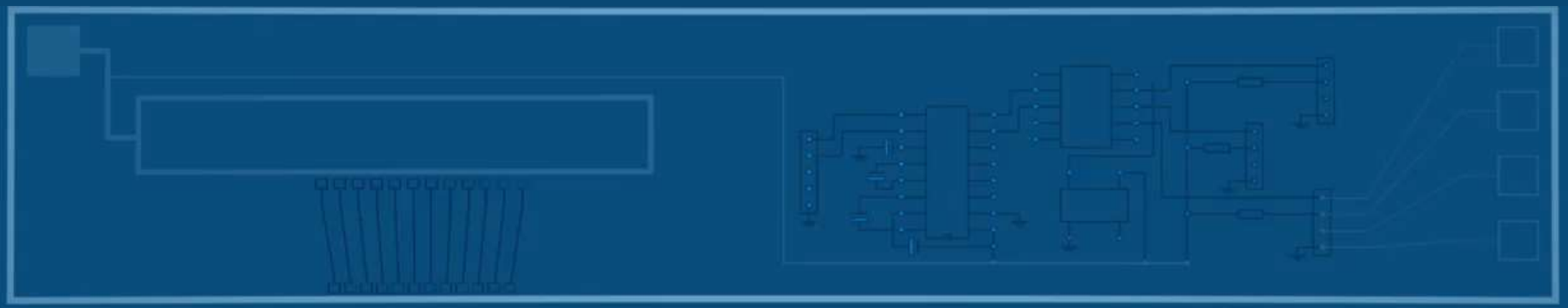
How? Overall

- Repast is faster than NetLogo in execution times.
- However, you can have a model in NetLogo in few houre, Repast can take weeks (depending on your programming skills).
- Although Repast is scalable, what about millions of agents (HPC)?
  - MASON
  - RePast C++ HPC
  - Custom



Summary

- Agent Based Modeling and Simulation can model complex non-linear problems.
- ABMS elevates system adaptation and learning.
- Use agents when autonomous interactions occur.
- Prototype with NetLogo, followed by RePast implementation.
- Interesting Technology Trends in ABMS:
  - Software Architecture using Agents rather than Objects.
  - Distributed Data Mining.
  - Network Security with Agents.



Thank You!

Questions?

References

- Vizzari, EASSS 2009 - Torino – 3-4/9/2009 Tutorial.
- CM Macal and MJ North, Tutorial on agent-based modeling and simulation, Journal of Simulation 2010.
- CM Macal and MJ North, AGENT-BASED MODELING AND SIMULATION, Proceedings of the 2009 Winter Simulation Conference.
- Paul Davidsson , **Agent Based Social Simulation: A Computer Science View,** *Journal of Artificial Societies and Social Simulation* vol. 5, no. 1.
- Rob Allan, **Survey of Agent Based Modelling and Simulation Tools, http://www.grids.ac.uk/Complex/ABMS/ABMS.html#SECTION00031400000000000000, visited 31-05-014 .**

The Runner ups…

NetLogo

The Center for Connected Learning (CCL) and Computer-Based Modeling, Northwestern University, USA.

Repast Simphony

Argonne National Laboratory, Chicago, USA.

MASON

George Mason University, USA.

Multi-

Agent **S**imulator **O**f **N**eighborhoods

... or **N**etworks... or something... ,