An Initial Glimpse of AnyLogic & Emergence: Modifying an Existing Model

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Announcements

• Office hours
  – Extra this week (Wednesday & Friday 10-11am)
  – Next week: Wednesday 12-1pm
• Please alert me to any AnyLogic installation/licensing issues ASAP
• First Friday class this week (in E62-446)
• Dates to watch
  – March 2: Assignment 1
  – March 9: Term project topic proposal
• Seeking expressions of interest in tutorials (email best)
Recall: Agent-Based Models

• Characteristics
  – One or more populations composed of individual agents
    • Each agent is associated with some of the following
      – State (continuous or discrete e.g. age, health, smoking status, networks, beliefs)
      – Parameters (e.g. Gender, genetic composition, preference fn.)
      – Rules for interaction (traditionally specified in general purpose programming language)
    • Embedded in an environment (typically with localized perception)
      • Communicate via messaging and/or flows
  – Local & Global Environments
• Emergent aggregate behavior
Recall: Organization in ABM

- ABM adopts the organizational style of object-oriented software engineering by clustering together the elements of state & behavior for entities.
- This facilitates convenient representation of:
  - Nested relationships (individuals in neighborhoods in municipalities, etc.)
  - Networked relationships (e.g. network of individuals, towns, farms, firms, etc.)
Contrasting Organization in Aggregate Stock-Flow & ABM

**Aggregate Stock & flow models**
- Within unit (e.g. city)
  - Subdivided according to state (e.g. # susceptible, # infective)
  - Each stock counts # units associated with that state
- State for different units of analysis are found in stocks & flows at same "level"
  - Summaries for city & country are both stocks in model
- Relationships between units implicit in data (e.g. connectivity matrix)

**Agent-based modeling**
- Within unit (e.g. city)
  - Subdivided according to constitutive smaller units (e.g. individual people)
  - Each unit maintains its own state
- The nested or networked relations among units of analysis mimic that in world
- Relationships are captured via references

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Infectives
Mean Time with Disease
Recovered
RecoverySusceptible
Incidence
Contacts per Susceptible
Per Contact Risk of Infection
Force of Infection
Mean Time with Disease
Birth Rate
Vaccination Initial Population
Initial Fraction Vaccinated
Annual Likelihood of Vaccination
Vaccinated Mortality
Birth and Death Rate
Mortality Rate
Susceptible Fraction of Population
<Time>
<Susceptible>
<Time>
random seed

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AnyLogic basics

• Multi-platform
• Declarative graphical languages
• Basic language: Java
• Rich library of built-in objects
• Continuous or discrete time/space
• Modeling approaches supported
  – System Dynamics
  – Agent-based
    • Regular & irregular spatial embedding, network embedding
  – Discrete event
Stock & Flow Models

• Feedback-focus
• Traditional graphical depiction
  – Stocks (state of system)
  – Flows (rates of change to the state)
  – Continuous variation in state
• Stocks are initialized, are then change according to flows
• Values of flows are determined by stocks & any other variables
Agent-Based Modeling

• Agent (actor) focused
• Traditional graphical depiction: State transition diagram
  – States
  – Transitions
  – Discrete variation in state
• Regular or irregular topologies connect between agents
  – Messages sent via connections
Network Embedded Individuals
Regular Spatial Embedding
Discrete Event Modeling

• Resource-based modeling
  – Queues
  – Processes
  – Flow charts
  – Capacitated resource pools
  – Send to
  – Attachment/detachment
“Network Modeling”
Irregular Spatial Embedding
Hybrid Models

• Much of the power of AnyLogic lies in its ability to integrate multiple types of modeling in a single model

• Attractive schemes
  – Agent-based using system dynamics for continuous agent state (c.f. age)
  – System dynamics using agent-based to determine flows
  – Agent-based using system dynamics for global dynamics
  – Agents entering into process-based health services
Example Hybrid Model
Advantages of AnyLogic
(as compared to other Agent-Based Modeling Software)

• Primarily declarative specification
• Less code
• Great flexibility
• Access to Java libraries
• Support for multiple modeling types
• Support for mixture of modeling types
Painful Sides of AnyLogic Education/Advanced

• Export of model results: Very limited support for retrospection on model results
• Need for bits of Java code
• Many pieces of system
• Pricy debugger
Opening an AnyLogic Example Model

Choose “Example Models” under the “Help” menu
Hands on Model Use Ahead

Load AnyLogic Example Model: SIR Agent Based.alp
Finding the Example Model

Click on “SIR Agent Based”

Exact location will vary with screen resolution
Model Focus: Spatial Spread of an Infectious Disease

• This model simulates the spread of an infectious disease in a regular space.
• The simulation starts with a single index infective case (towards lower right of space).
• Natural history of infection involves progression from Susceptible to Infected (& Infective) to Recovered.
  – There is no waning of immunity in the original model.
• If a given person is infective, the infection can spread from that person to their neighbours in the 4 cardinal directions (“North”, “South”, “East”, “West”) (i.e. Up, Down, Left, and Right).
Viewing the Model Structure

Double click on “Person” to see the associated state transition diagram. This diagram represents in a stylized fashion the progression of infection.
Run the Model (Right Click the Experiment “Simulation” & select “Run”)

[Diagram showing a simulation model with nodes labeled as Susceptible, Infectious, Recovered, etc., and arrows indicating transitions between states.]
Press this button to start model execution.
Example of Emergent Behaviour
Make Sure Model Time is Visible

If no model time is visible on the bottom of the window, press this button to add a “model time” output.
Select “Model Time” here (so a check mark appears) (If a checkmark is already present, just click back on the output window)
The Updated Window Should Include a Model Time Output
Stylized Measurement 1

- How Long Does it Take for The Infection to Reach the Top or Left Boundaries?

- We’ll compare this to the situation with other assumptions regarding the progression of the infection (as encoded by model “parameters”)

Press this button to stop model execution
Close the window using this button
We’ll Now Modify the Model
Note that May Get this Warning (Can Ignore)
Right click here to bring up the menu.
Select “Copy” from the menu.
Right click here to bring up the menu.

Select “Paste” from the menu to paste in a new experiment (a copy of the existing one).
Your Screen Should Look as Follows
Changing the Name of the Experiment

1) Select here (the new experiment) so we can edit its properties (characteristics)

2) Select the “General” tab

3) Type the name “SlowRecovery” for the new experiment
Selecting the Model Used for this Experiment

Select "Main" here
Altering Assumptions Regarding Infectiousness Duration (via Parameters)

1) Select the “Parameters” tab

2) Make the illness duration 50
Run the Model (Right Click the Experiment “SlowRecovery” & select “Run”)
You Should See Something Like This

How quickly does the wave of infection take to reach the top border? How does this compare to the situation where we assumed a shorter period of infectiousness? Why?
Adding a Transition

Click on “Statechart” to view
The statechart-related palette
Adding a Transition

To add a transition to the statechart
Drag from “Transition” on the Palette to
the “Recovered” state
Connecting the Two States

1) Dragging the transition should have led to a connection here. While holding down the mouse button, drag the mouse to here and only then release the mouse button.

2) Click on the other end of the transition.
Give the Transition a Name
(Make sure it is selected by clicking on it)

Type the name ("waningImmunity") here
Setting the Duration Until Immunity Wanes

1) Make sure this is set to “Timeout”

2) Set the waning time to 100
Let's Run the Revised Model!

Run the original experiment (“Simulation”) with the newly changed model by right clicking on “Simulation” & selecting Run.
After Starting the Model, You Should See Something Like This. What Happens as Time Progresses?
What Happens as Time Progresses?
Use the Run Button & run the “SlowRecovery” Experiment
Slow Recovery Results

This time, only a few scattered Yellow (Susceptible) individuals are visible.
As Time Progresses, Little Internal Structure – Why?
Stylized Measurement 2

• How Long Does it Take for The Infection to Reach the Top or Left Boundaries?
• How does this compare with the earlier experiment with a shorter duration of immunity?
• **Bonus question:** What would an aggregate (random mixing) model have predicted?
Observations

• A brief & informal glimpse of AnyLogic’s user interface for building, modifying & running models

• Take-Home Points
  – Much of a model can be described graphically
  – Running a structurally simple model can lead to complex emergent patterns over time & space
  – Modifying the model quantitative assumptions (described by parameters) can significantly change results
  – Modifying the model structure can qualitatively change model behavior