## Building a Hierarchical Metapopulation Model Nathaniel Osgood

Using Modeling to Prepare for Changing Healthcare Needs Duke-NUS April 16, 2014

# Capturing Multi-Level Hierarchies: A Frequent Modeling Need

- We frequently have hierarchies of environments and actors
  - Region/Municipalities/Neighborhoods/Individuals
  - Region/Municipalities/Schools/Children
- As is widely recognized in multi-level modeling (e.g. HLM), these hierarchies frequently exert successive levels of influence
- Frequently these hierarchies are also associated with their own *structural* and *dynamic complexities*

# One Example of Structural and Dynamic Complexities

- Municipalities may be arranged in transportation networks (road, rail, air connections)
- People may exhibit primarily contact patterns within a given municipalities
- People may move between municipalities

# AnyLogic Flexibility

- While certain AnyLogic elements are most commonly associated with part of the project hierarchy, we can use them in many places, e.g.
  - Statecharts can be placed within "Main"
  - Populations of other agents can be placed within "Agents"
- Partly because of this flexibility, we can create structural hierarchies in AnyLogic that parallel the hierarchies in the world



## Hands on Model Use Ahead



## Load Previously Built Model: MinimalistNetworkABMModel

Suggest Saving as "HierarchicalCityPopulationModel"

## One Example

- Main contains a population of Cities
   Arranged in one type of network
- City contains a population of Persons

Arranged in another type of network

## **Initial State**

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## Click Right on Project Name & Choose "Paste"

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## Result



## Rename "Person1" as "City"

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## Open "Main"



# Click on "population"

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## Click (once) on "City" and Drag into "Main" Canvas & Drop



## Result



## Click on "city" in Main Canvas, set name to "cities", use "environment" & set replication to 10

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In "Advanced" tab in "Properties" window for "environment", make sure that "Network Type" is "Distance Based", and "Connection Range" is "250"

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## Double-click on "City" in "Project" Window



## Adding a Municipal Population

Click (once) on "Person" and Drag into "City" Canvas & Drop

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#### Click on "person" in "City" canvas, set name to "cityPopulation"&set replication to "uniform(10, 200)". Result:



In "Environment for other agents" properties of "Properties" window for "City", set "Network Type" to "Scale free" and the "Width" and "Height" both to **75** 

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## Run the Model



## Change the Relative Size for Cities & People

Double-Click on "City"

Expand "Project" Window Hierarchy on left under "City" to get to "oval" (Under "presentation"



# Drag to Enlarge



## **Recenter on Origin**



# Model



## Now Move the Origin for Placing People to Upper Left of City



## **Centered View**



## Add a Statistic at the City Level



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#### Add a Function the "Person" canvas. Name it "moveToRandomCity". Set the "General" tab properties as follows

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## Set "Code" Tab for "moveToRandomCity" as follows

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▼ Function body	· · · · · · · · · · · · · · · · · · ·
<pre>//destinationCity.applyNetwork(); int countCities = city.main.cities.size(); int randomCityIndex = uniform_discr(0, countCities - 1); destinationCity = city.main.cities.get(randomCityIndex); goToPopulation(destinationCity.cityPopulation); destinationCity.applyNetwork();</pre>	
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#### Add a Function to "Person" canvas, named "moveBetweenSpecifiedCities". Set "General" tab properties as follows

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<pre>cityTo.applyNetwork();</pre>	
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## Add an Event to the "Person" canvas. Name it "desiringIntercityMove"

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# Run the Model. People Should Now be Moving Around between the Cities



# Extension 0: City-Level Variability

- Different distributions for cities
  - LogMeanIncome
  - LogStdDevIncome

# Extension 1: Adding Name Labels to Cities

## Add "Name" Parameter to City



## Establishing a Text Field (Label) for Cities



# Set Dynamic "Name" Text Field Property



## Establishing Collection (Array) of City Names

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## Setting the "Name" Parameters of Successive Cities Upon Creation

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# Running



**Extension 2: Extending** the Model with Infection Spread (Note that this does not build on Extension 1)



## Hands on Model Use Ahead



## Load Previously Built Model: "HierarchicalCityPopulationModel"

Suggest Saving as

"HierarchicalCityPopulationModelWithInfectionSprea

# Model Upon Opening



## In "Person", add a Statechart Entry Point

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# Add a "Susceptible" State

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## Add an "Infective" State

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## Add a "Recovered" State

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# Neaten Up (as Aesthetics Require)

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#### Add a "Recovery" Flow Rate is 0.1 (implying mean residence time of 10)

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# Add "InfectionIncidence" transition

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## In "Agent" Properties for "Person", Route the message to the "infectionStatechart"

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#### Add an "exposureTransition" to Spread Infection (This sends an "Infection" message every time unit)



#### Add a Variable called "color" This is of type "Color", and should have initial value "Black"

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# Set Color for "Infective" State to Green

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# Set Color for "Infective" State to Red

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# Set Color for "Recovered" State to Gray

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► Description	<ul> <li>Projects &amp;</li> <li>HierarchicalCityPopulationModelW</li> <li>G City</li> <li>G Main</li> <li>Person</li> <li>Simulation: Main</li> </ul>	Properties      Progress     Recovered     Recovered     Show name     Ignore     Fill color:     Default     Color=GRAY;     Exit action:     Description	v color	Image   Image </th

## Set the Formula for Person's Oval "Fill Color" Property to be "color"

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## Run the Model

The Infection Spreads locally, and a bit between Cities





## Add a "meanRecoveryTime" parameter to "Person"

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# Set the "Recovery" Rate to the Reciprocal of "meanRecoveryTime" Note that need to Request up 2 levels

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## Note that Experiments now have a "meanRecoveryTime" parameter

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## Request Creation of a New Experiment

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## Call the new Experiment "RecoveryTime100"

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Experiment Select an experiment type, speci	ify a name and choose a root (top-level) active object.
Name: Main active object class (root):	Recovery100 Main V
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Copy model time settings fro	om: Simulation 🗸
	< Back Next > Finish Cancel

## For this Experiment, Assume a "meanRecoveryTime" of 100

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#### Click on the original Experiment ("Simulation") Rename it to "RecoveryTime10"

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## Create a 3<sup>rd</sup> Experiment, called "Baseline"

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# Set "Baseline" to Assume a "meanRecoveryTime" of 200

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# Run the Baseline Experiment

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# **Output from the Baseline Experiment**



#### Set the "Stop Time" for the Final Experiment to "500" (in the "Model Time" tab for the Properties of the experiment")

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# Do the same for the "RecoveryTime10" Experiment

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## Do the same for the "RecoveryTime100" Experiment

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