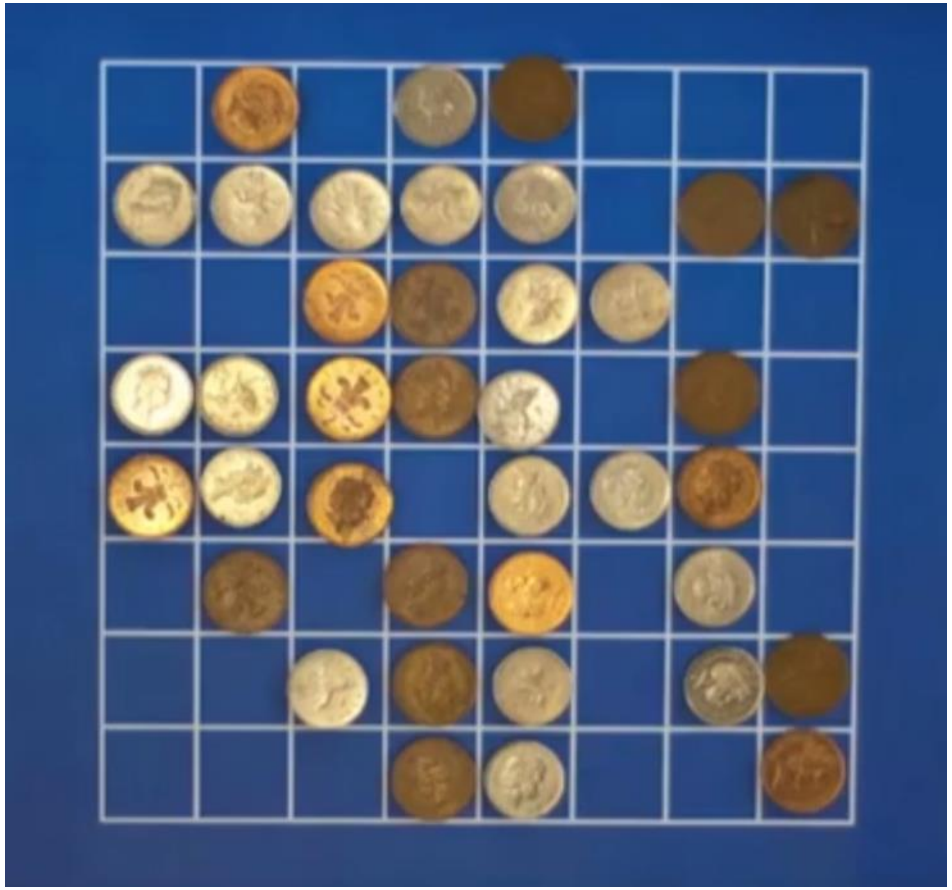
SIMULATING SEGREGATION

Complex Adaptive Systems, 2021

Mathew Page

Schelling's segregation models

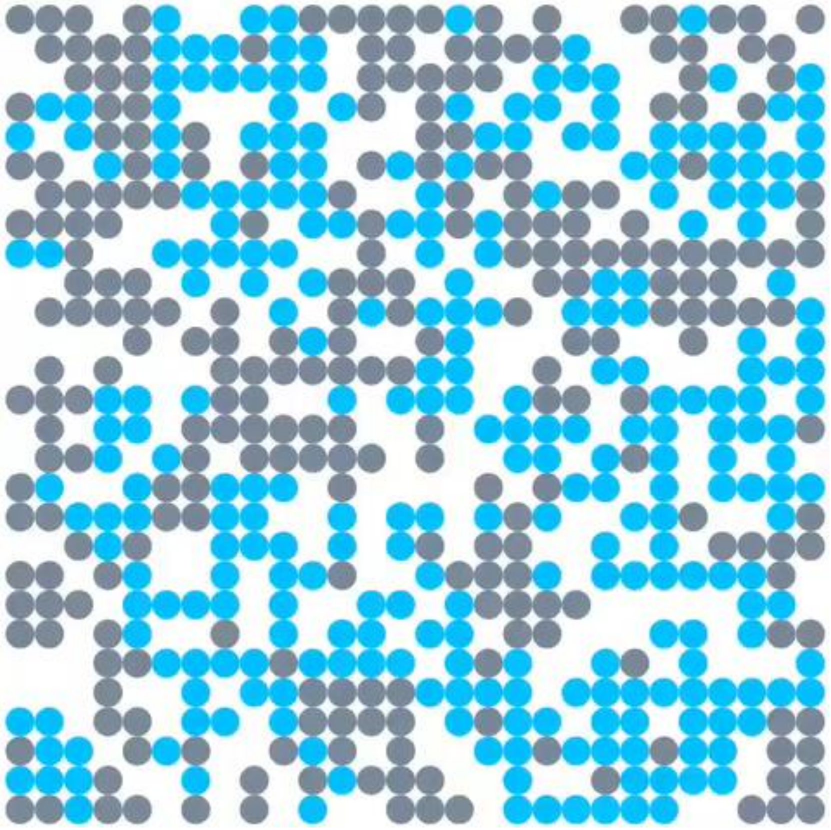
- One of the earliest applications of individual-based modelling applied to social systems
- Schelling used theoretical models to explore ethnic segregation processes in the US
- Segregation can emerge with low levels of same-group preference, even when no one explicitly desires it



https://www.sandtable.com/a-coin-and-paper-model-of-segregation/

Basic Model

- Symmetrical grid
- Random initial distribution
- Agents are identical except for colour
- Spaces are identical – have no qualities
- One agent per space
- Static population
- Bounded Environment



Schelling, T. (1971) Dynamic models of segregation, Journal of Mathematical Sociology, 1, pp. 143–186

Basic Model

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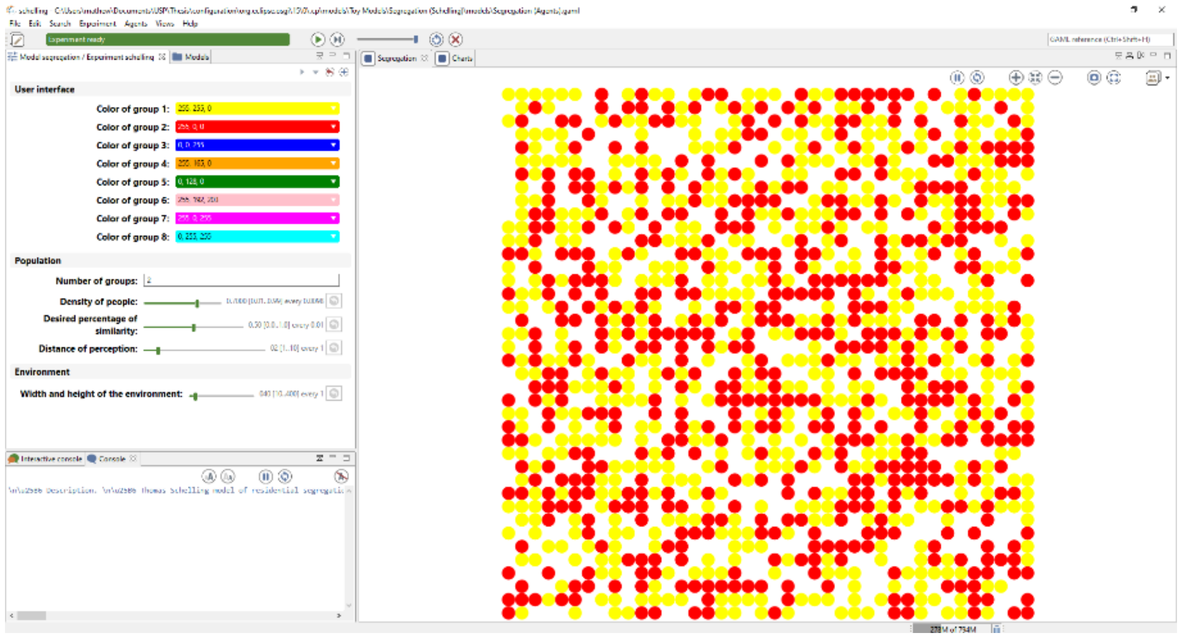
Goal in CAS project

➔ Real Urban Area (STAGE 1)

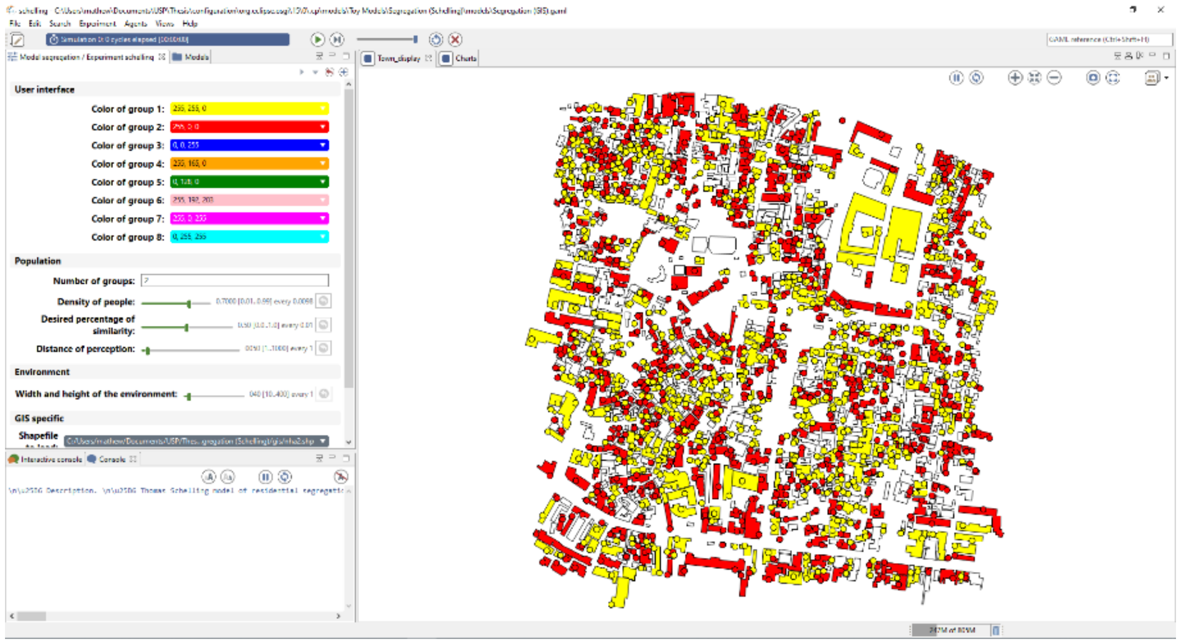
➔ Empirically-informed initial distribution (STAGE 2)

GAMA - Two pre-existing models in library

Basic grid



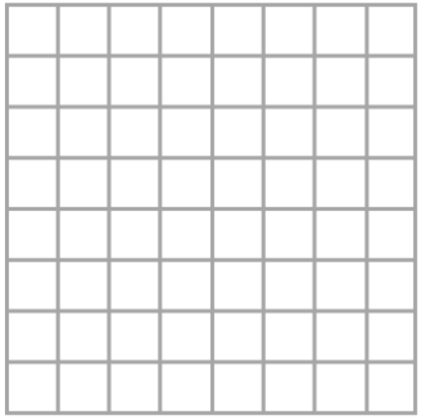
Vector-based model

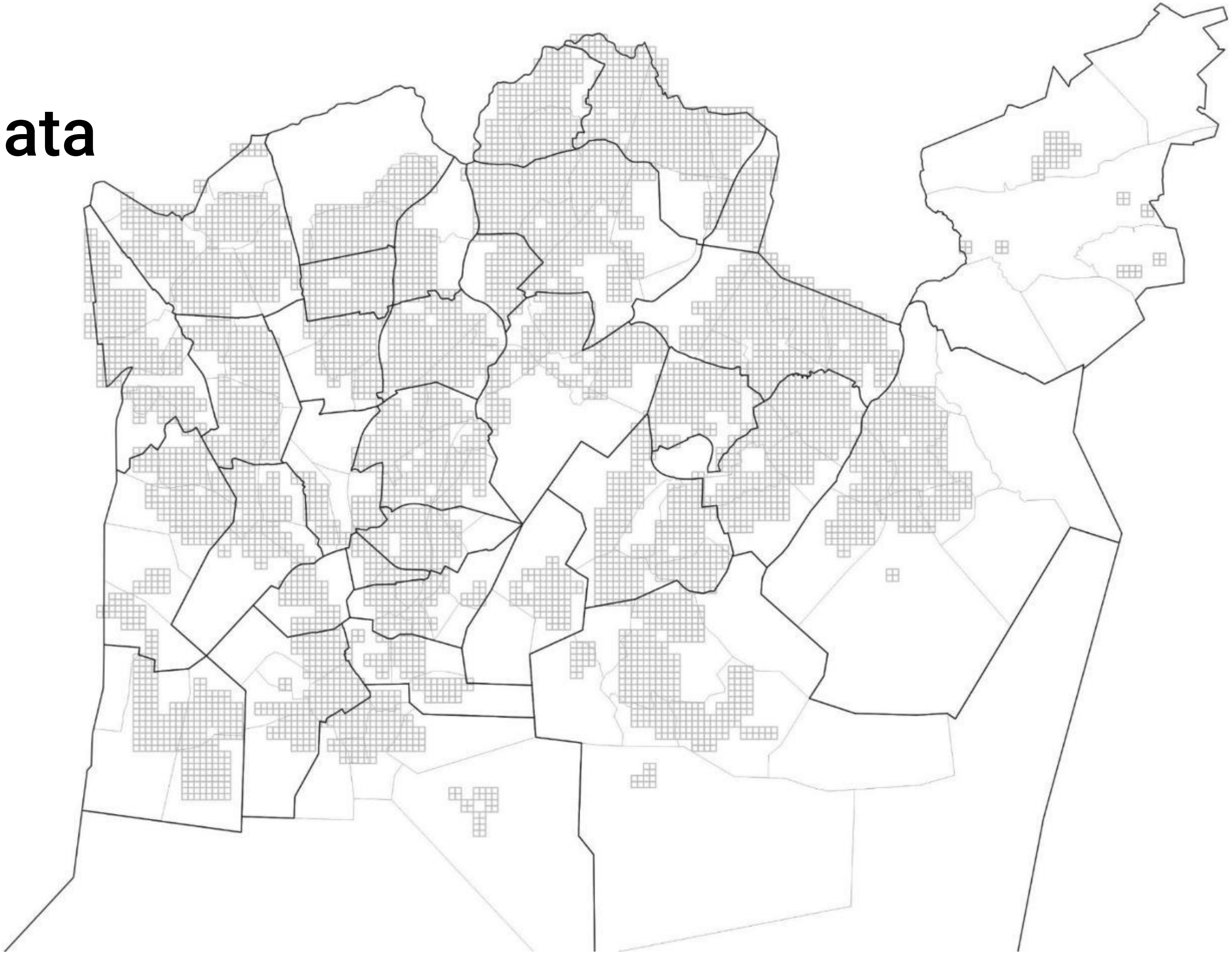


Stage 1:
From Grid to Vector Data

Statistics Finland
Grid Database

- 250m x 250m Grid Cells





Stage 1: Testing: OK

- Random initial distribution of one agent per cell
- 2 different colours
- Parameters as per Schelling

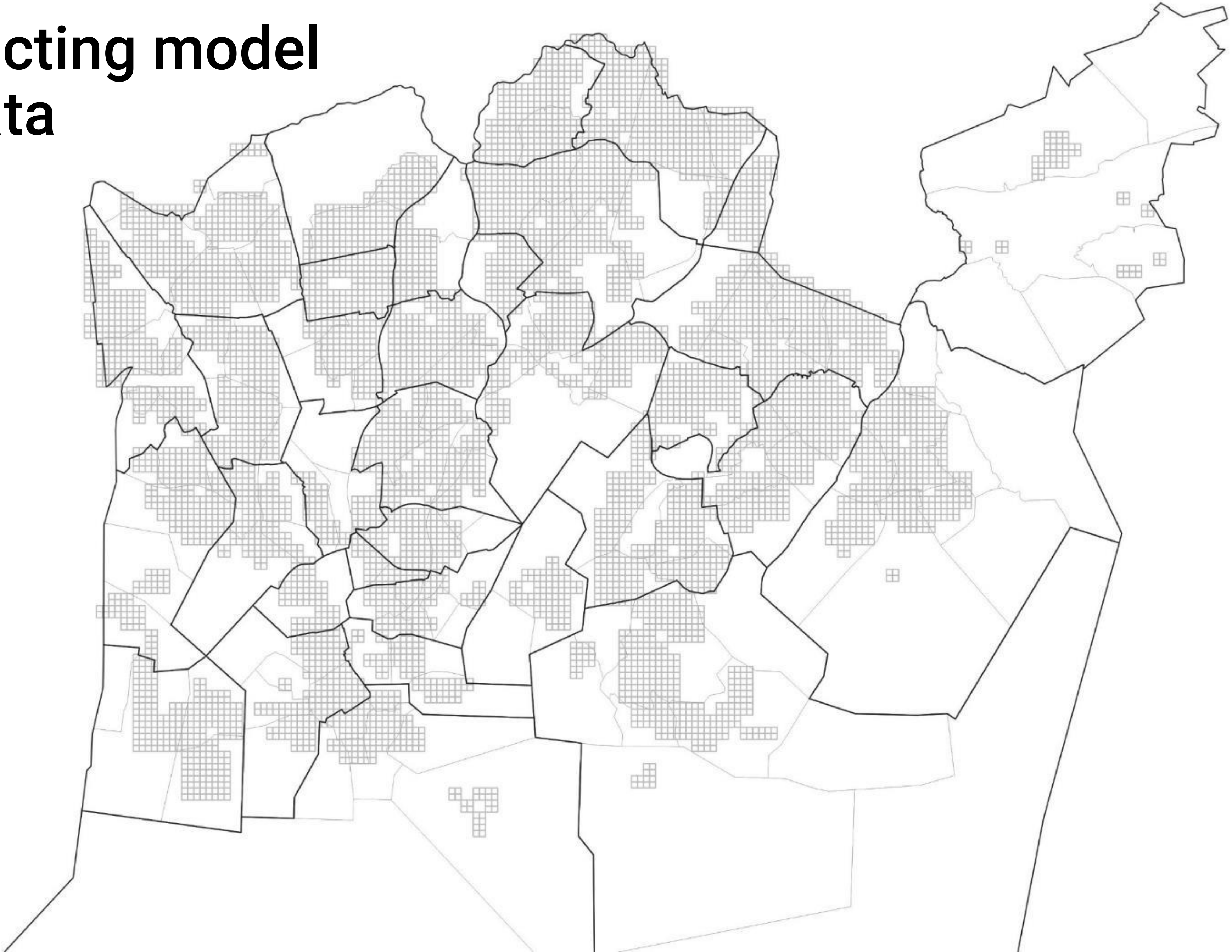
Stage 2 : Constructing model with empirical Data

DATA: Statistics Finland Grid Database

Socio-economic Segregation

Spaces
- 1,806 grid cells (250x250m)

Agents
- Household income groups – low, med high *(each grid cell contains number of households in each income group)*
- 280,000 households *(Computational costs too great)*

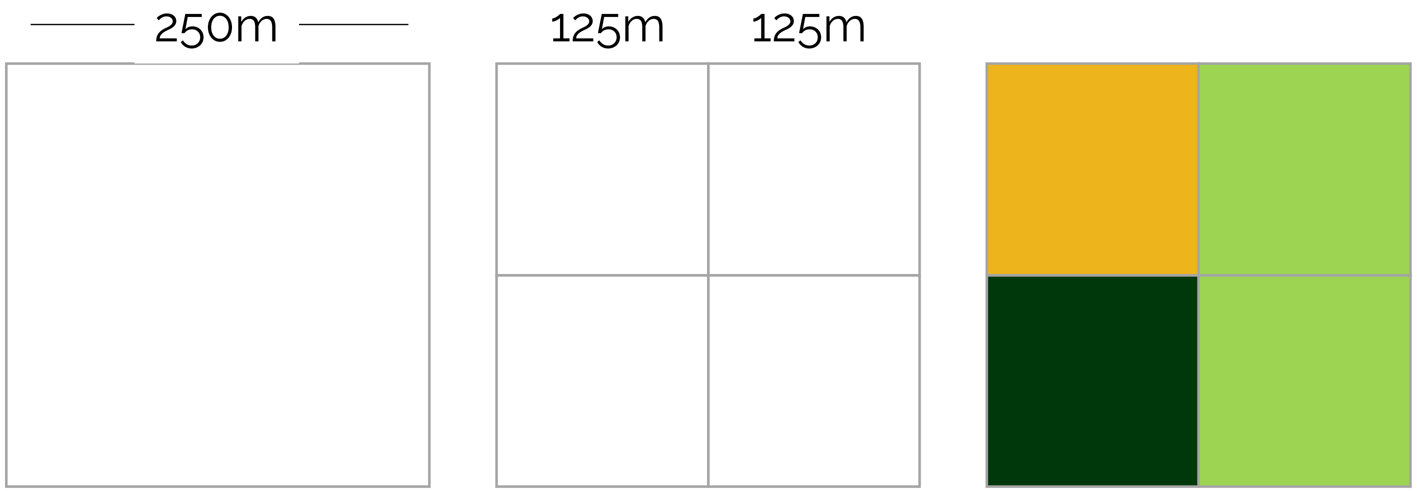


Stage 2 : Creating the Spaces

- To create a 'representative' model each 250m grid cell was divided into 4
  - Spaces given characteristics based on Income status of households

Example:

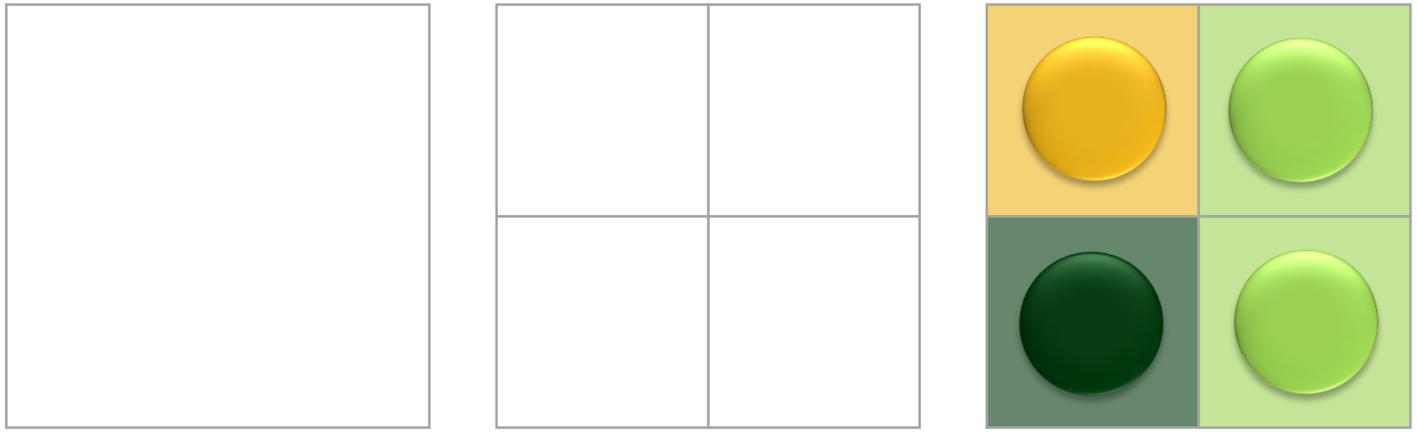
23% low-income = 1 space
56% mid-income = 2 spaces
21% high income = 1 space



*Cells with less than 10 households are privacy protected– these cells were deleted from the model

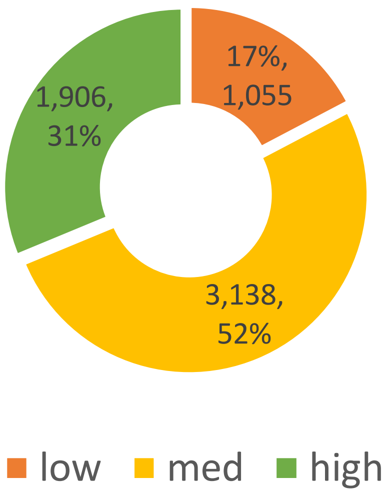
Stage 2 : Creating the Agents

- Same process – 1 agent allocated per space
- Agents given an income status which matched the space

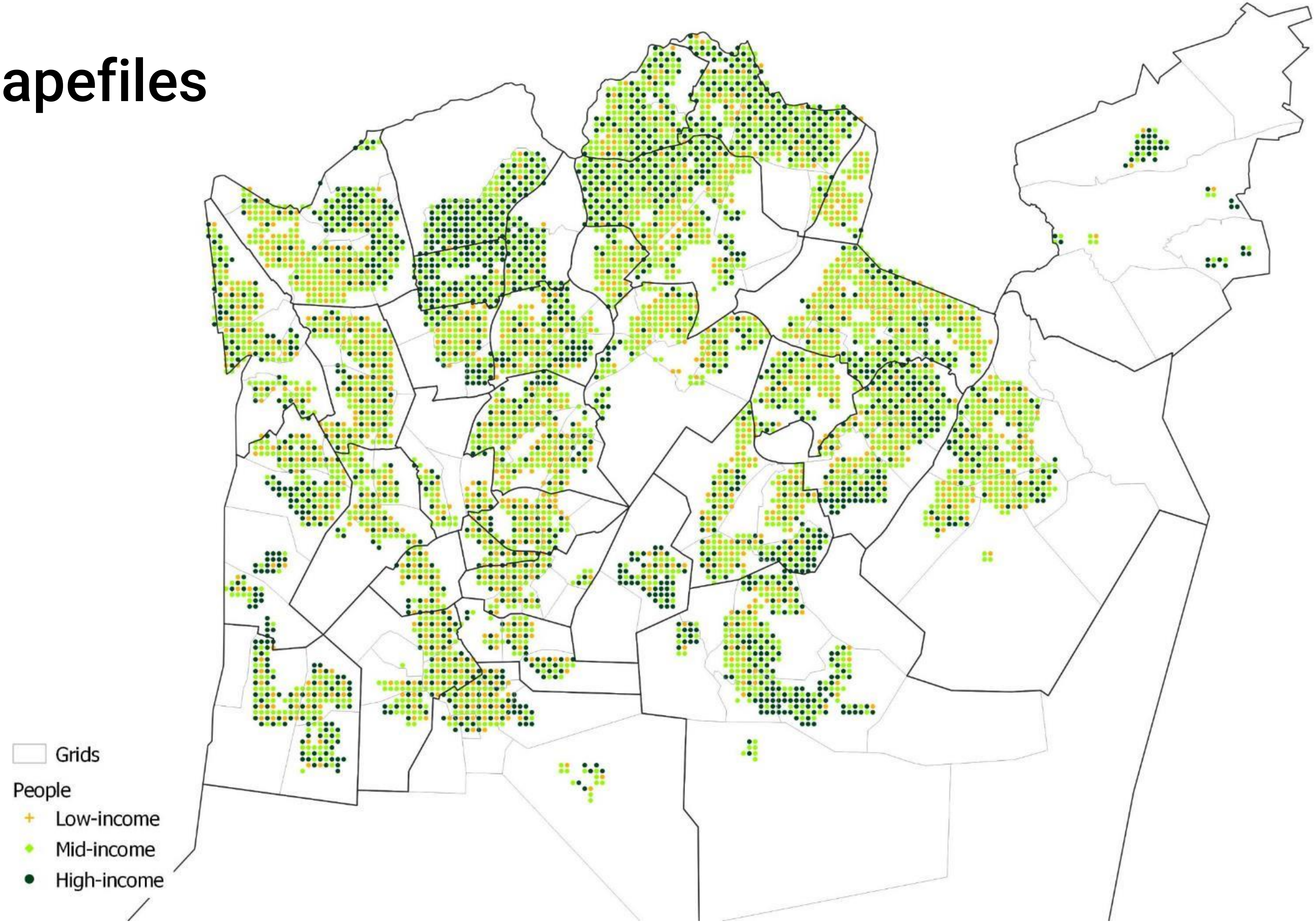


Stage 2 : Shapefiles

- **6,099 agents**
- **6,099 spaces**

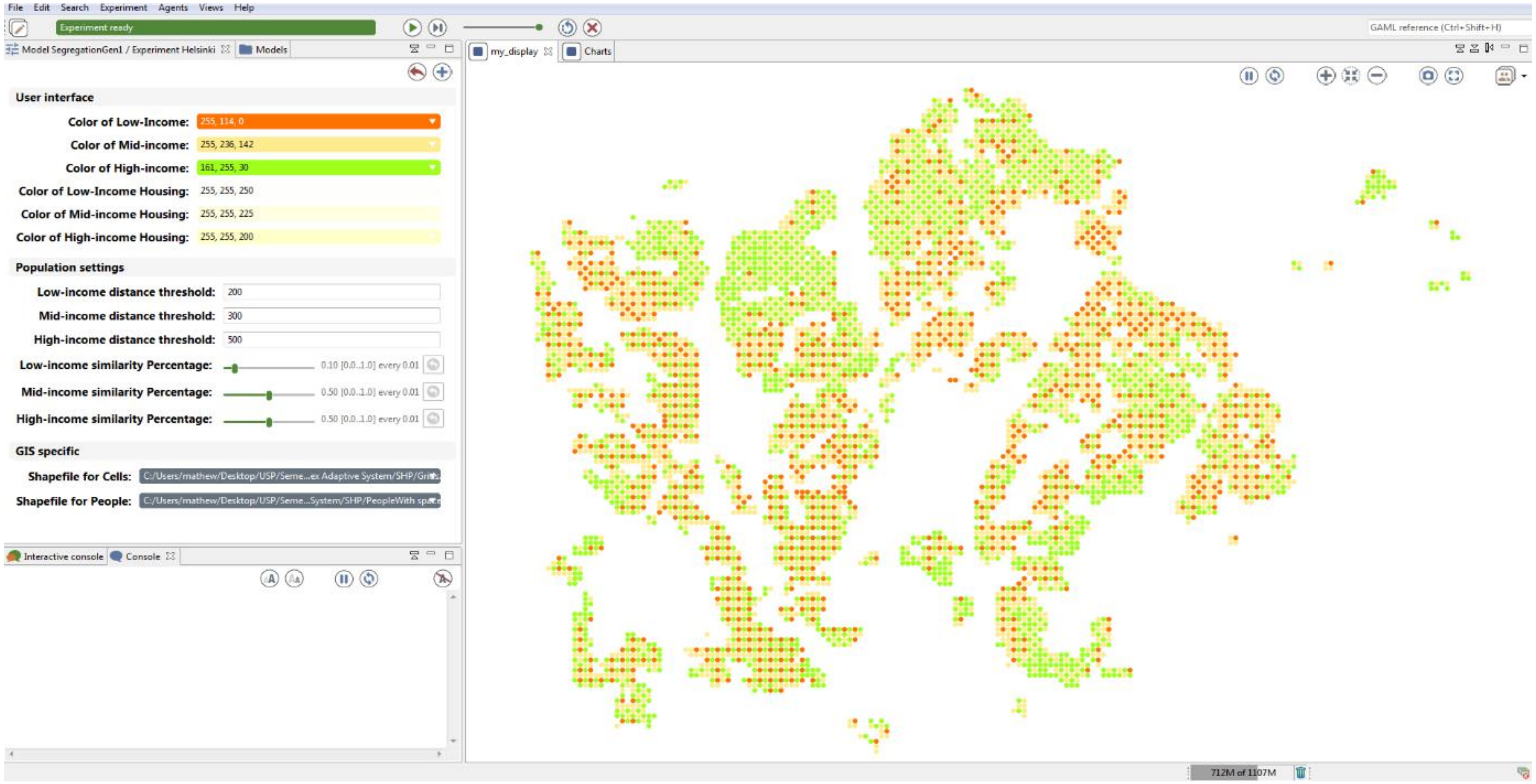


! Whilst cells are divided proportionally, this does not equate the regional proportions (density)



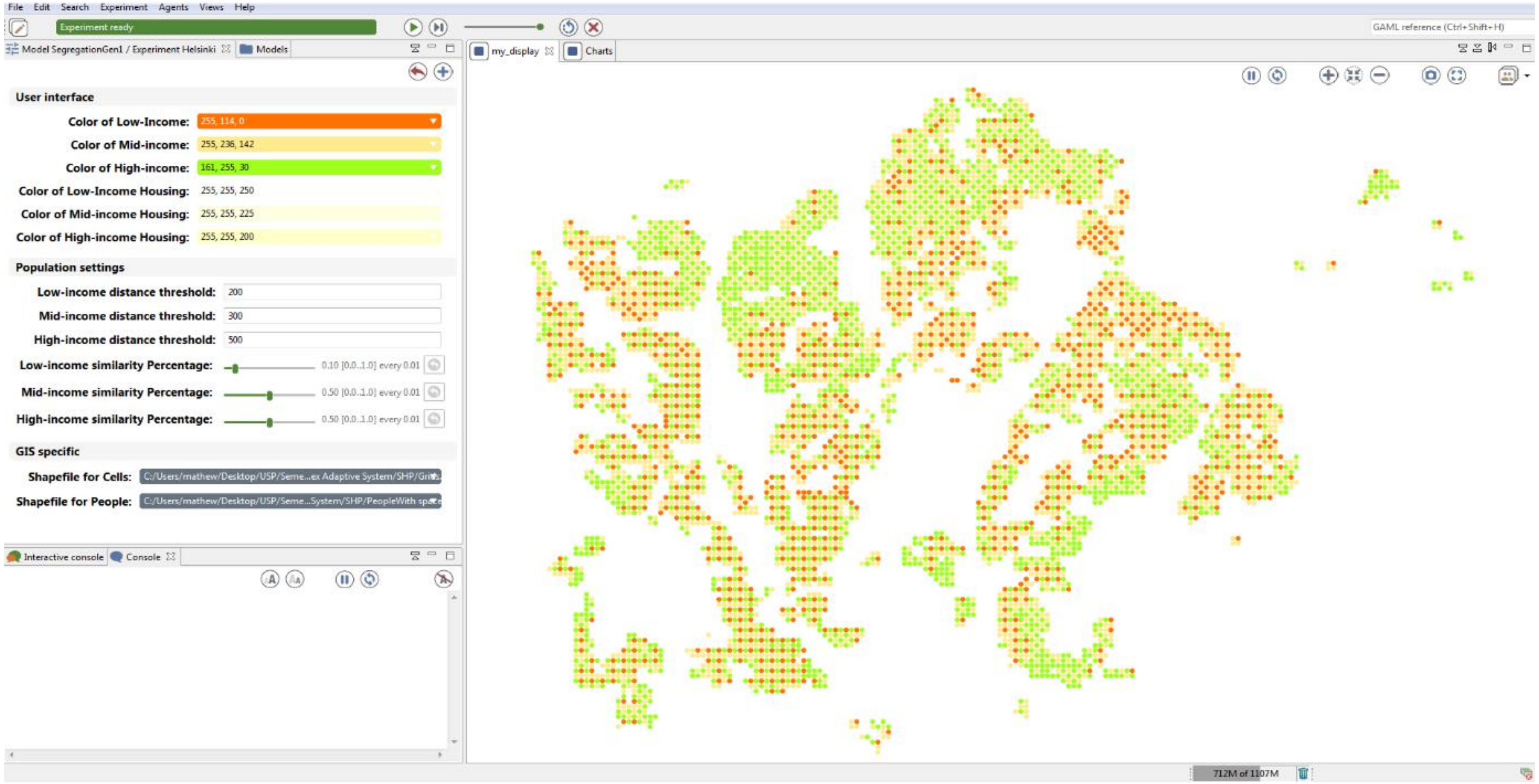
Stage 2 : Testing

Initialisation = OK



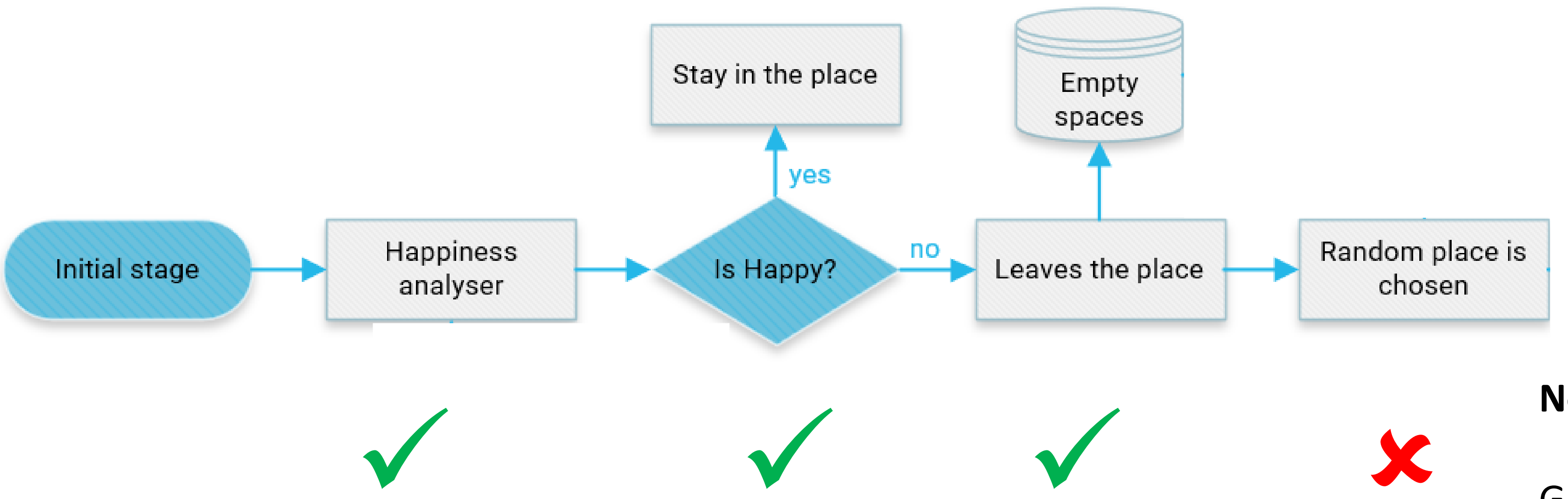
# Stage 2 : Testing
Cycles = FAIL

Agents do not move!



# Stage 2 : Testing
Cycles = FAIL

PROCESS: CYCLE

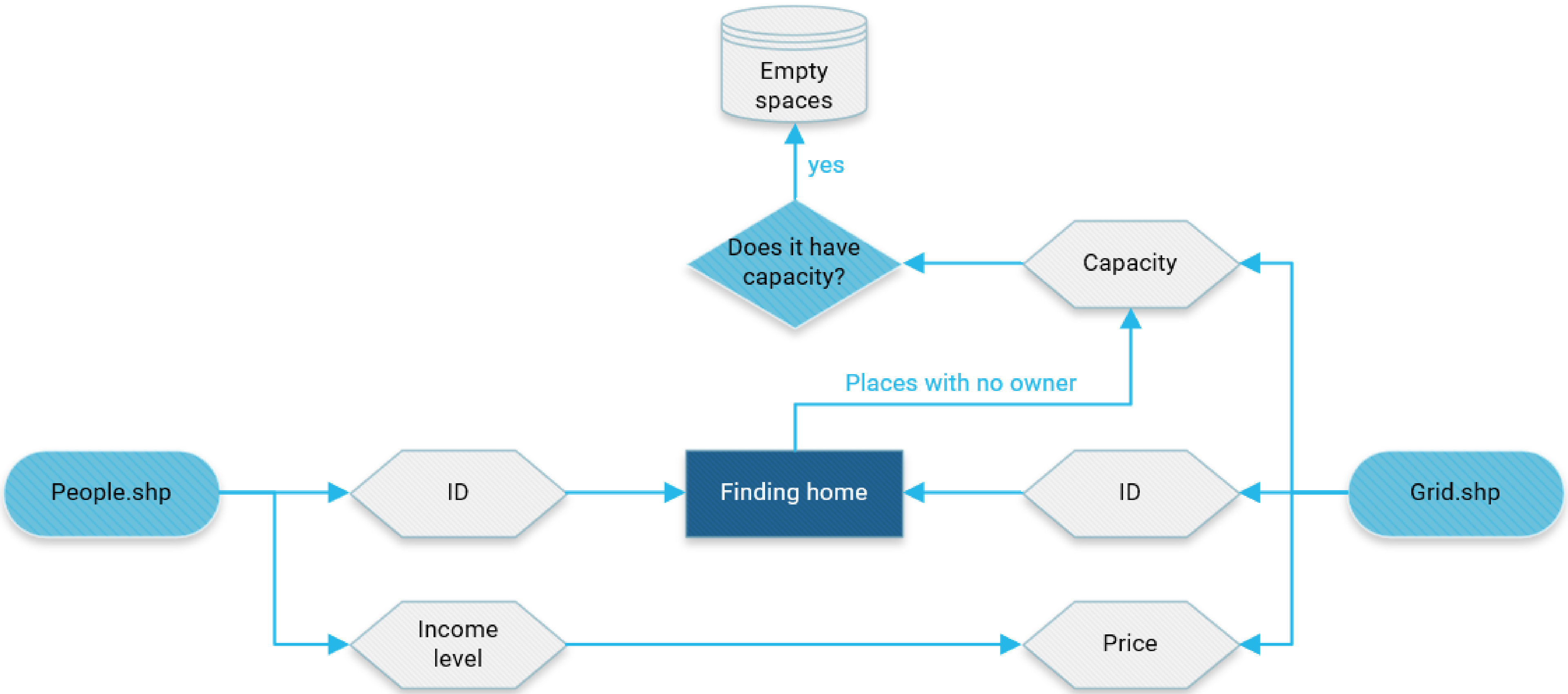


No vacant spaces were assigned

Grid data only includes inhabited areas, and any cells with less than 10 households were deleted

Solution: Create some vacant cells

Stage 2 : Initialisation process



Stage 2 : (re)Creating the Spaces

- To create a ‘representative’ model each 250m grid cell was divided into 4
  - Spaces given characteristics based on Income status of households

Example:

23% low-income = 1 space
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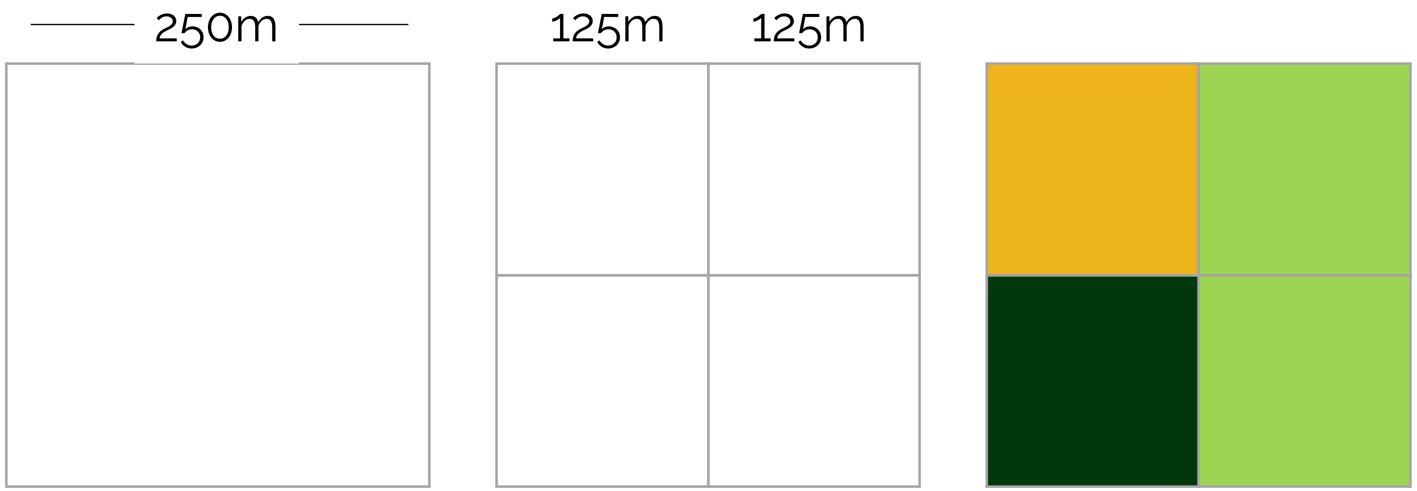
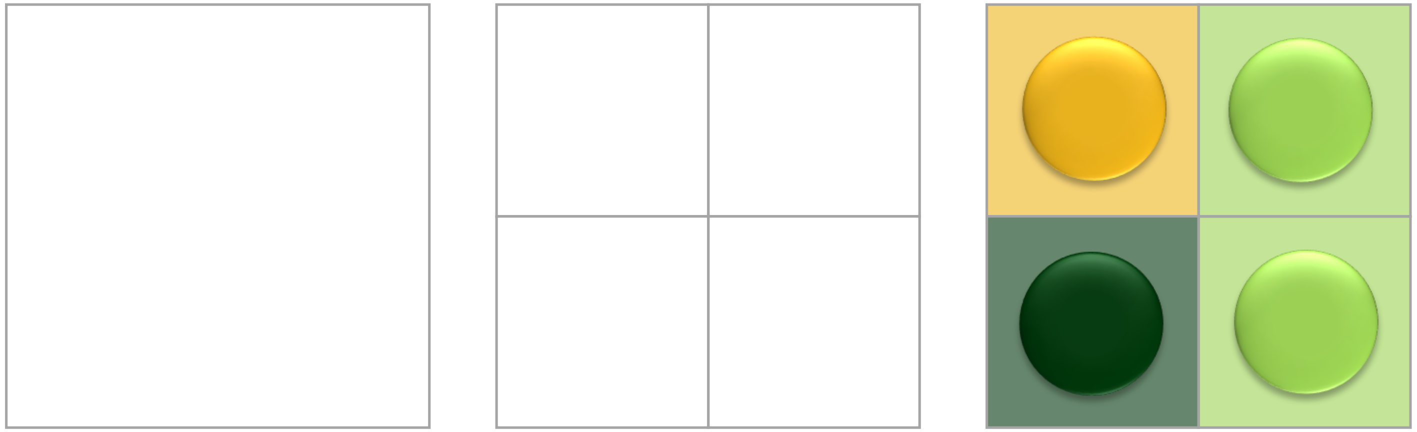


~~*Cells with less than 10 households are privacy protected– these cells were deleted from the model~~
***Privacy protected cells are created as ‘vacant cells’ and are assigned low-income status**

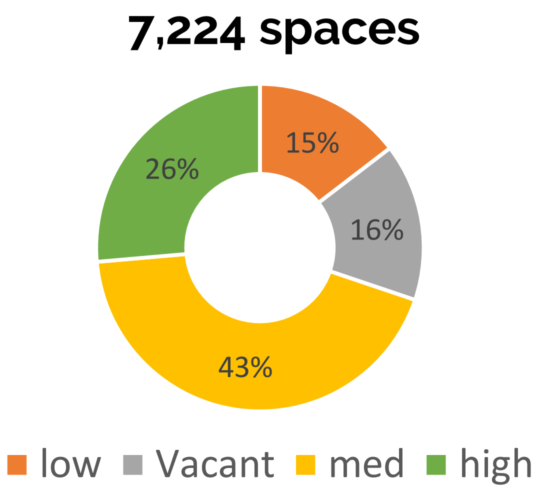
Stage 2 : (re)Creating the Agents

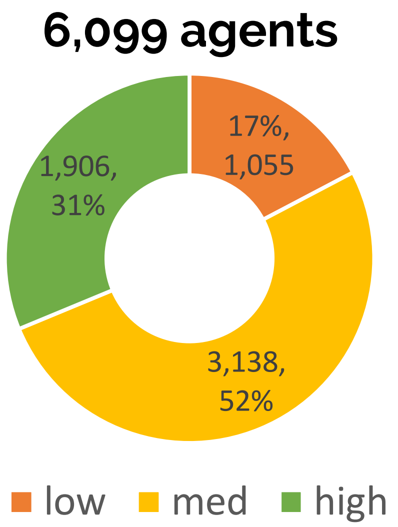
- Same process – 1 agent allocated per space
- Agents given an income status which matched the space

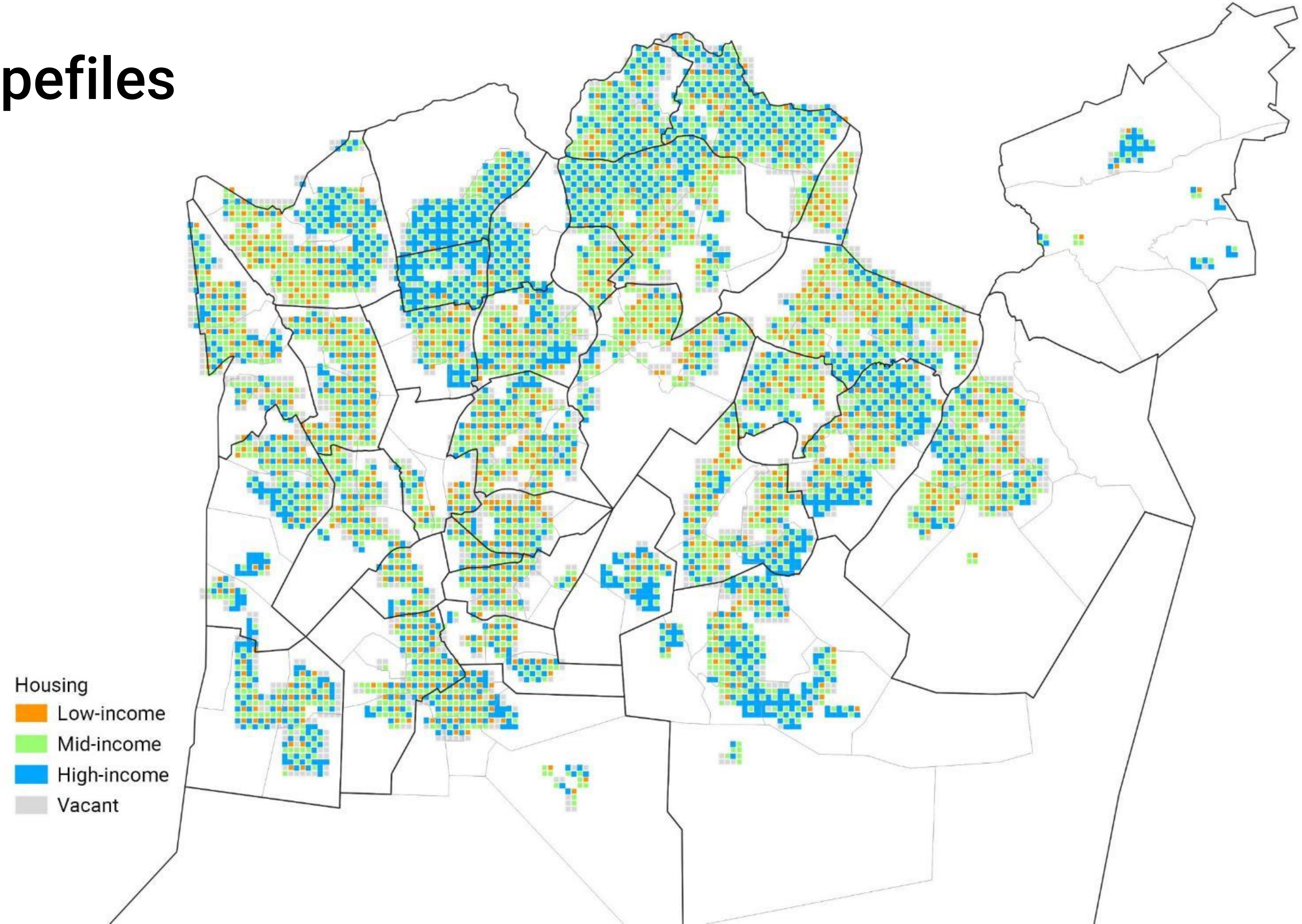
***No agents created for vacant cells**



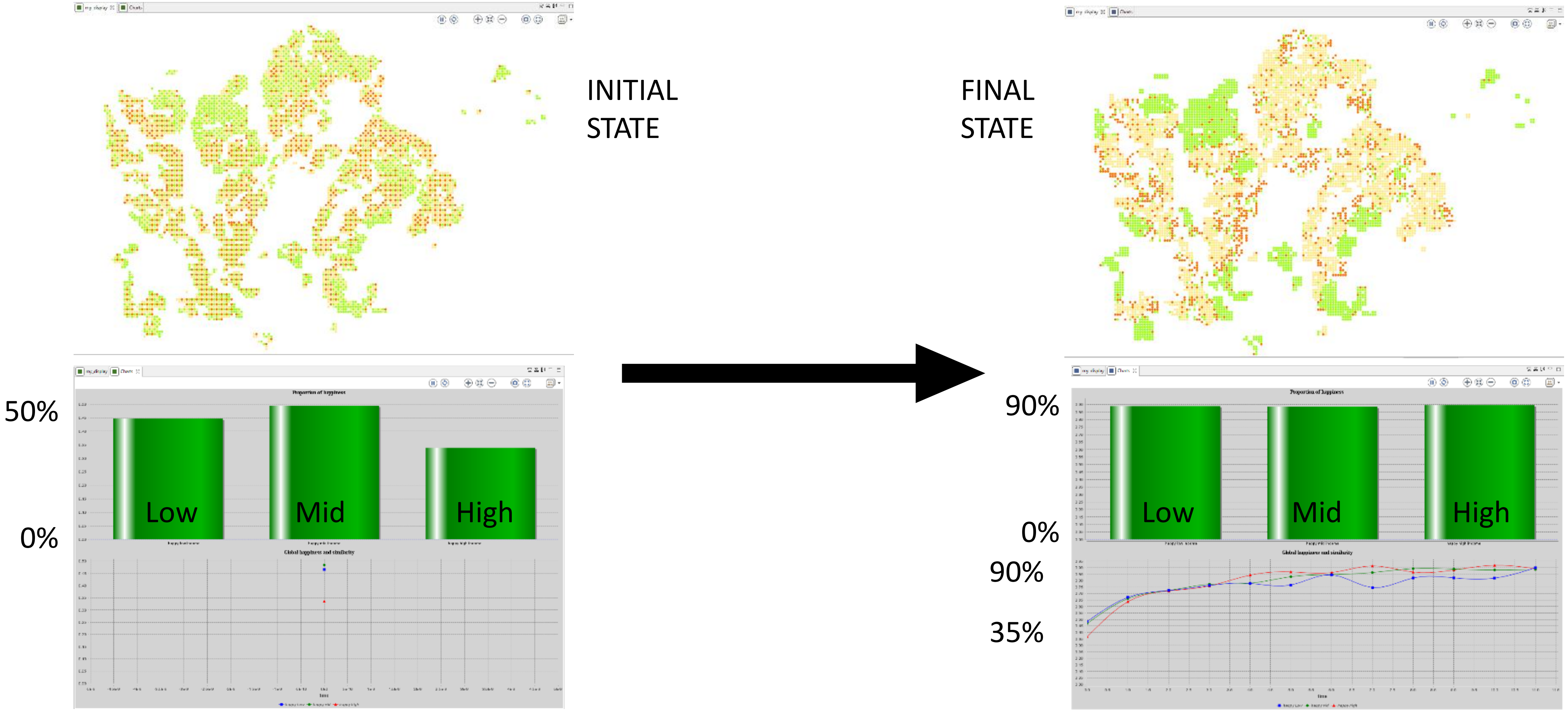
Stage 2 : Shapefiles







# Stage 2 : Testing
Cycles = OK



Basic Model

- Symmetrical grid
- Random initial distribution
- Agents are identical except for colour
- Spaces are identical – have no qualities
- One agent per space
- Static population
- Bounded Environment
- Within-group preferences are consistent

Goal in CAS project

➔ Real Urban Area (STAGE 1)
➔ Empirically-informed initial distribution (STAGE 2)
➔ Agents have different economic resources (STAGE 3)
➔ Spaces have different ‘prices’ (STAGE 3)

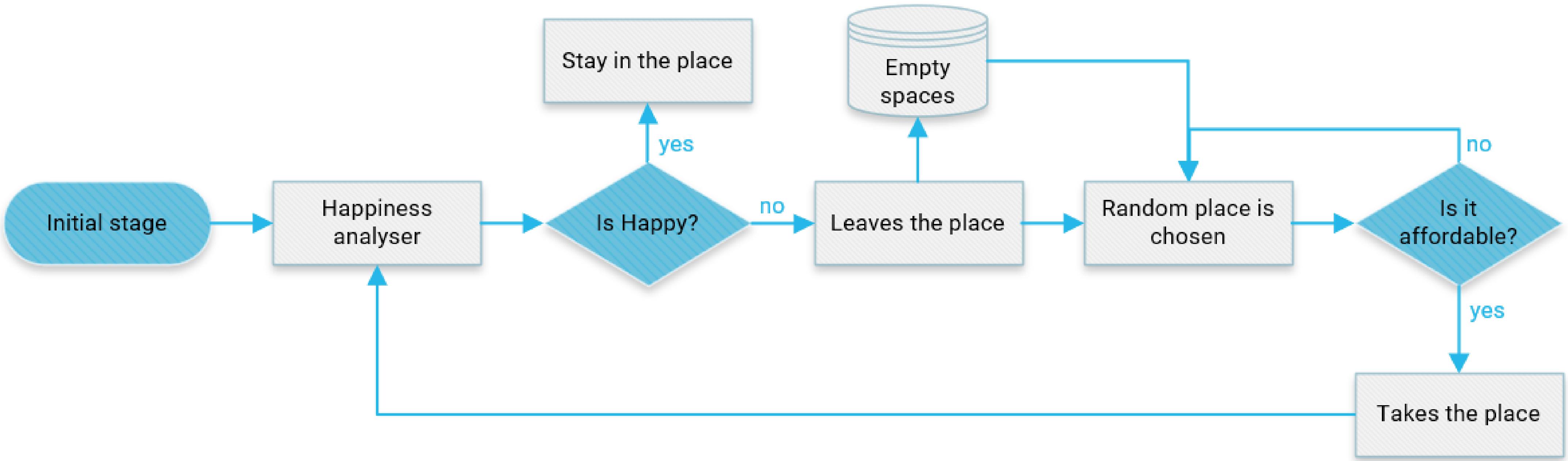
Stage 3: Agents ability to migrate is limited by their economic resources

- **NEW RULE**: Agents can only move to a location which they can afford

- Precisely:
  - Low income agents can move to low income spaces
  - Med income agents can move to low or medium income spaces
  - High income agents can move to low, medium or high income spaces

- Spaces do not evolve, prices remain stagnant, regardless of who is living there.

Stage 3 : Updating agent migration process

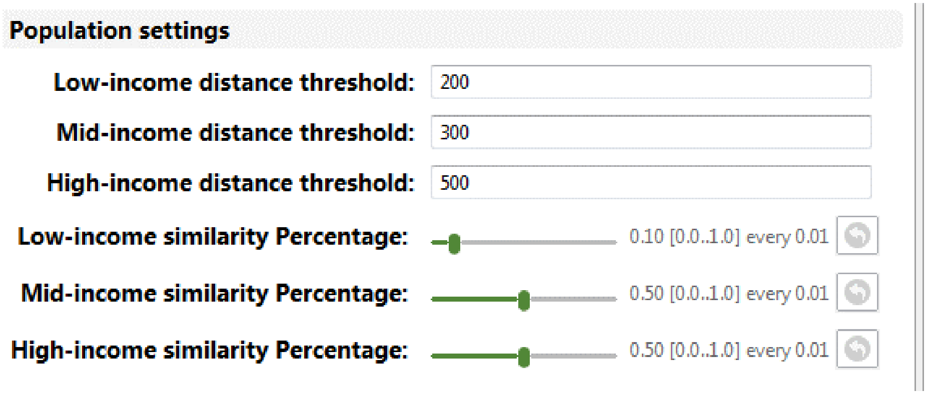


Stage 3: Setting some guidelines for testing

Our Parameters of Focus

- Neighbourhood Size
- Agent preference

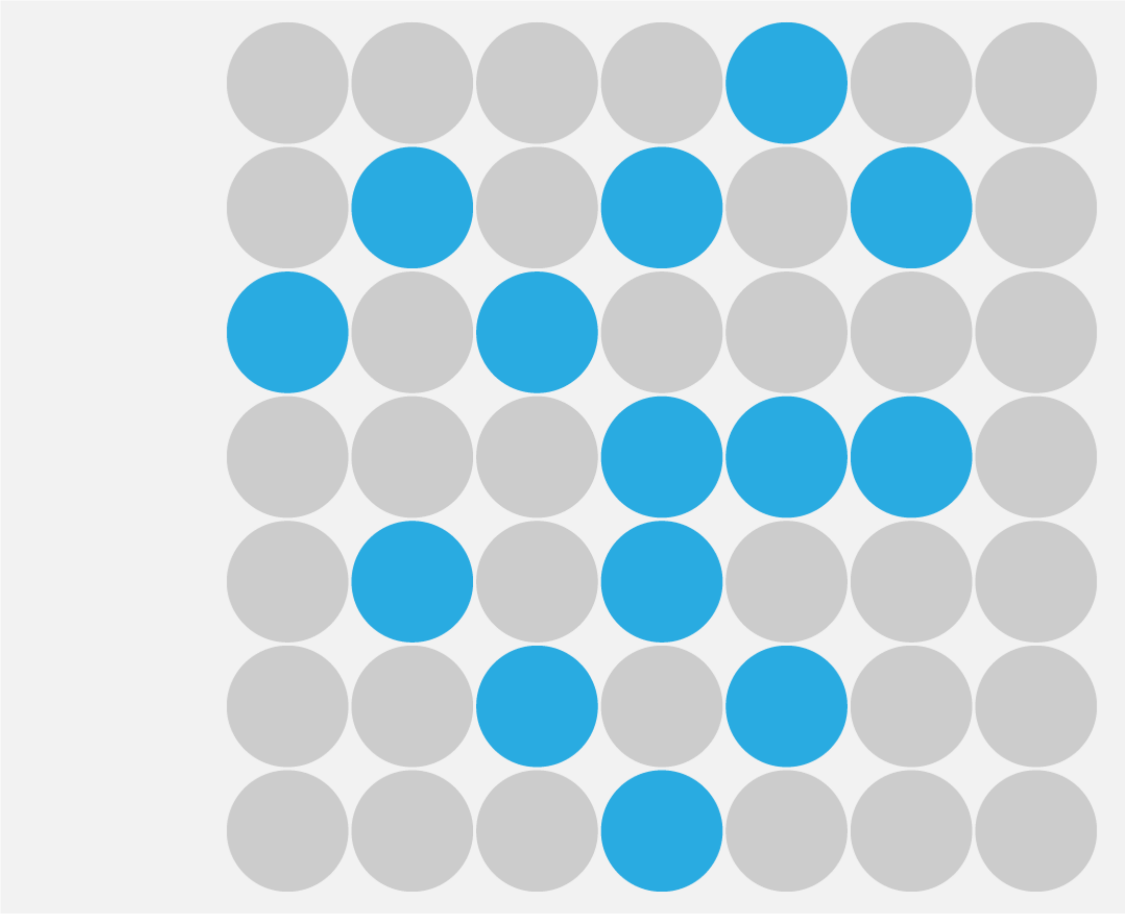
Added an Interface to Model:



Neighbourhood Definition

We used a **spatial proximity** definition for neighbourhood - calculated using buffers from each agents relative location

Neighbours: 25
Similar Within Distance: 10
Similarity Percentage: 40%



Agent Preference

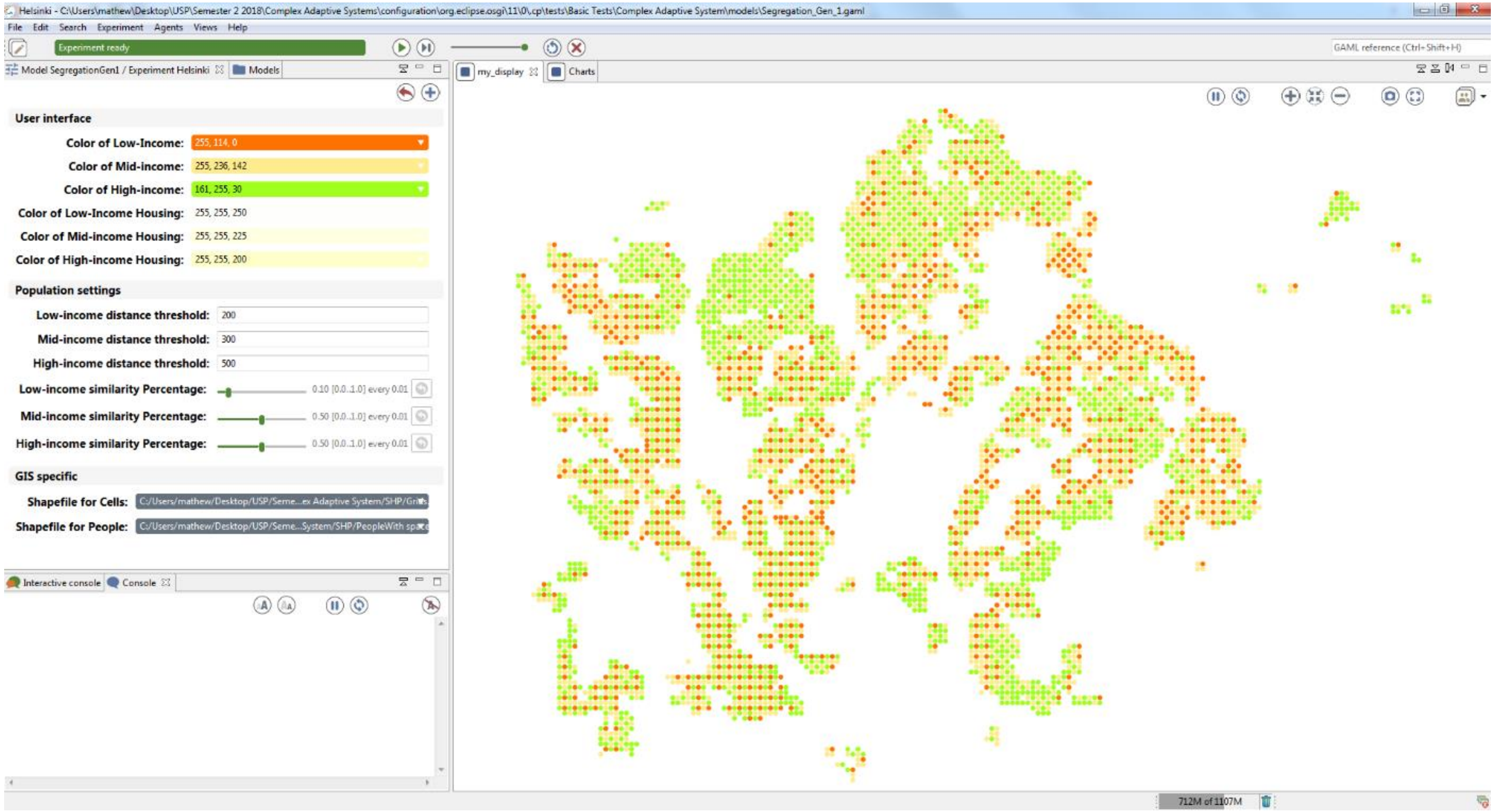
Initial Agent Preference Settings:

- Medium and High Income have preference to live away from Low Income
- Low Income are happy to live with Medium and High Income

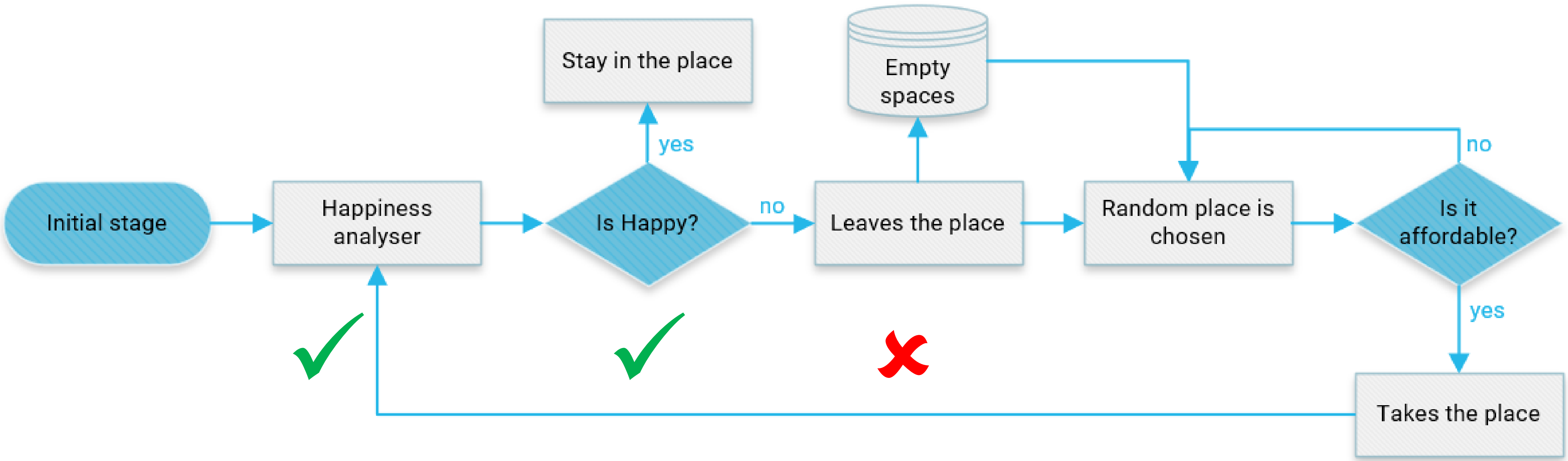
Stage 2 : Testing

Cycles = POTENTIAL ERROR

- Low income agents aren’t moving
- High and Medium Income agents cannot find suitable locations



Stage 2 : Testing
Cycles = POTENTIAL ERROR



As low income agents were given no preference – they were always happy and did not move.

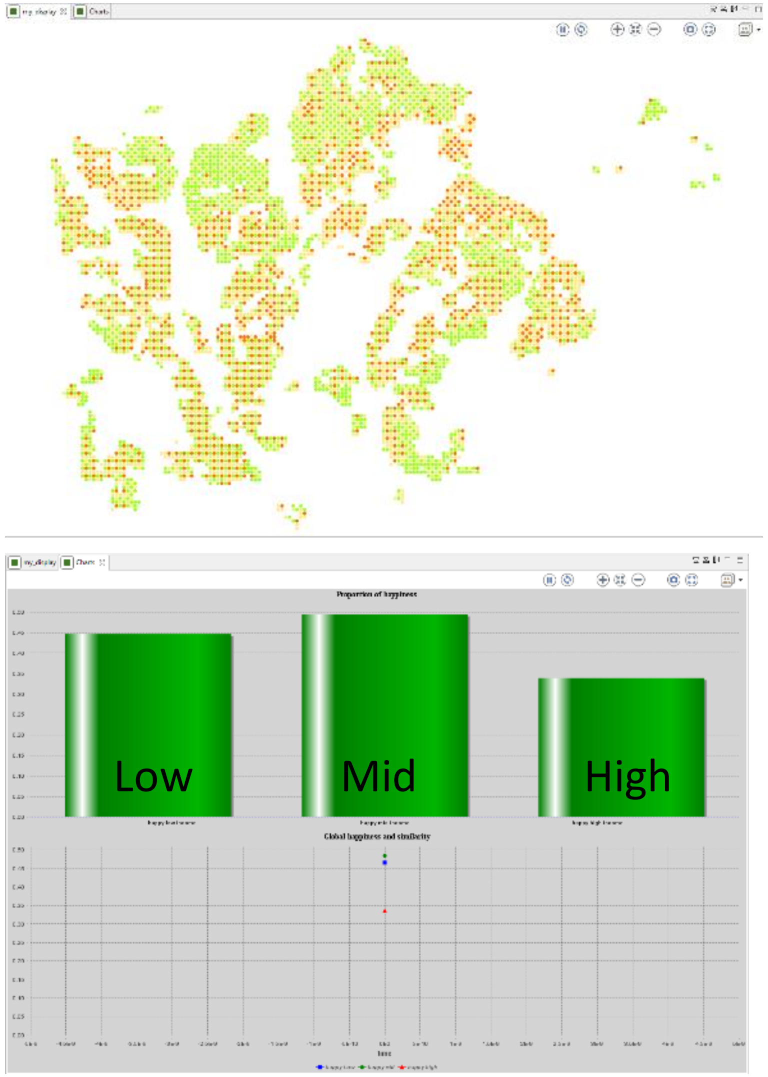
As the starting position was relatively integrated, this meant that other agents could not achieve their preference levels.

Solution: (10% preference set for low income agents)

Stage 2 : Testing
Cycles = OK

50%

0%



INITIAL
STATE

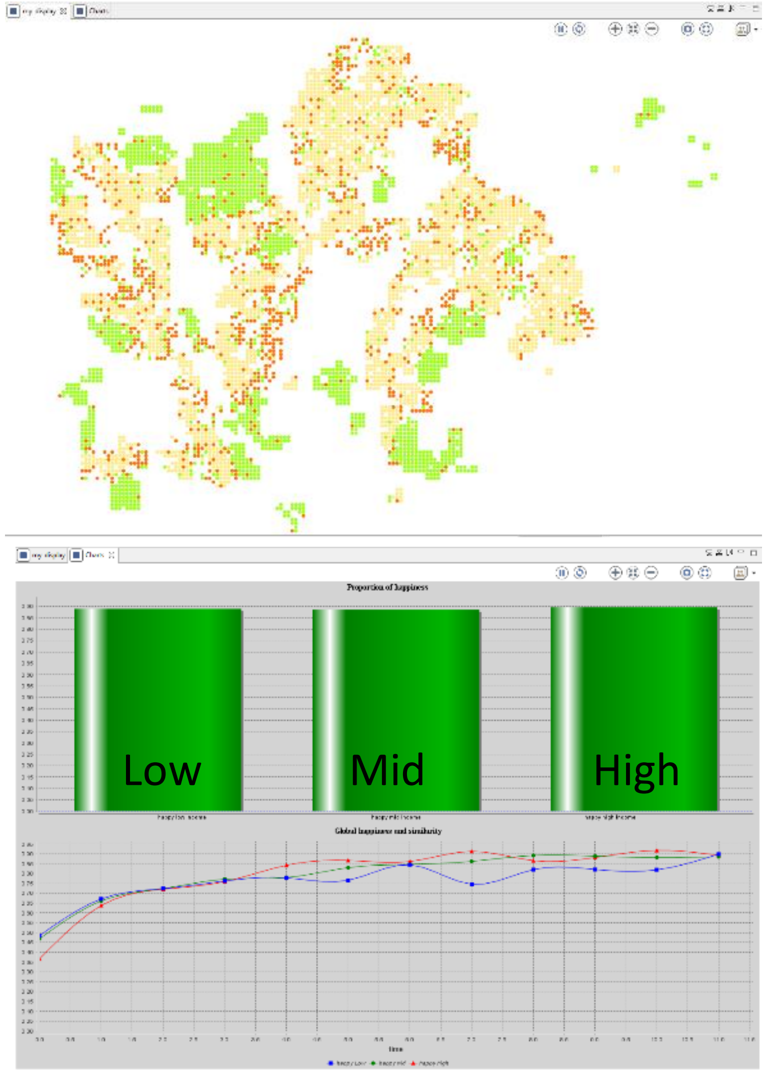
FINAL
STATE

90%

0%

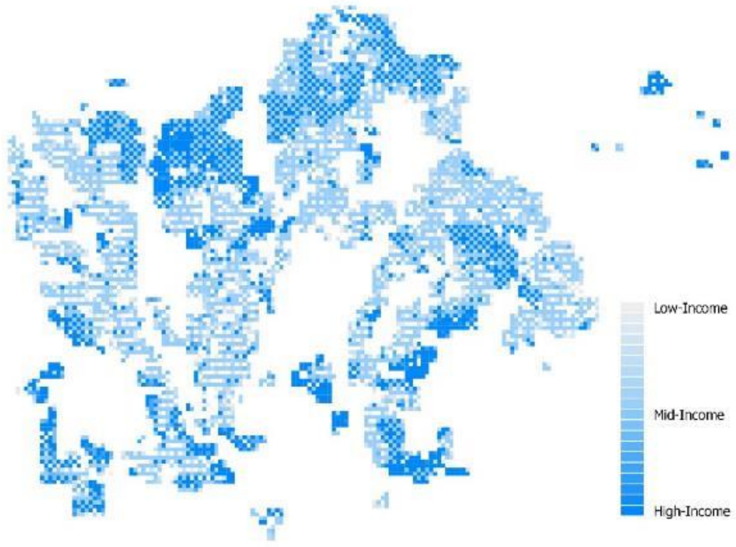
90%

35%

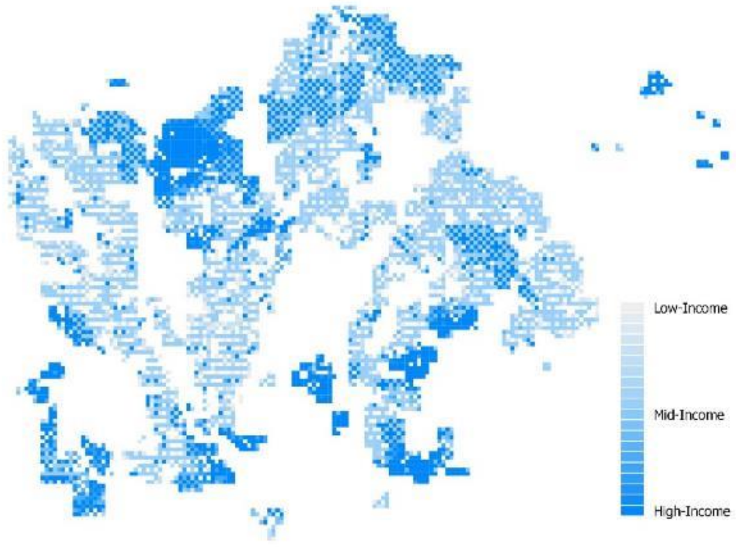


RUN SIMULATIONS AND EXPORT DATA

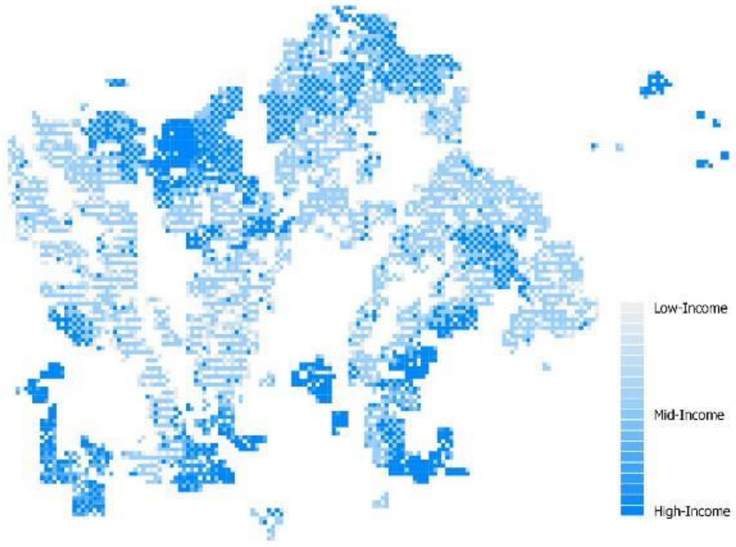
Results
30% Preference for like-neighbours



250 M



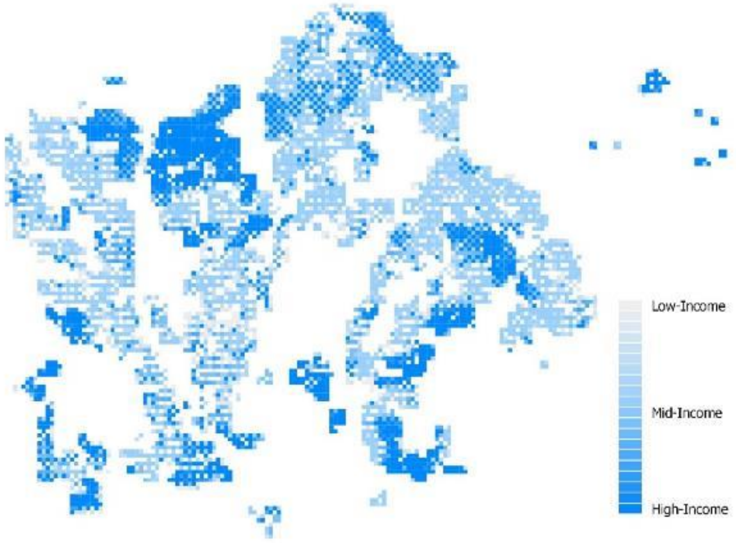
500 M



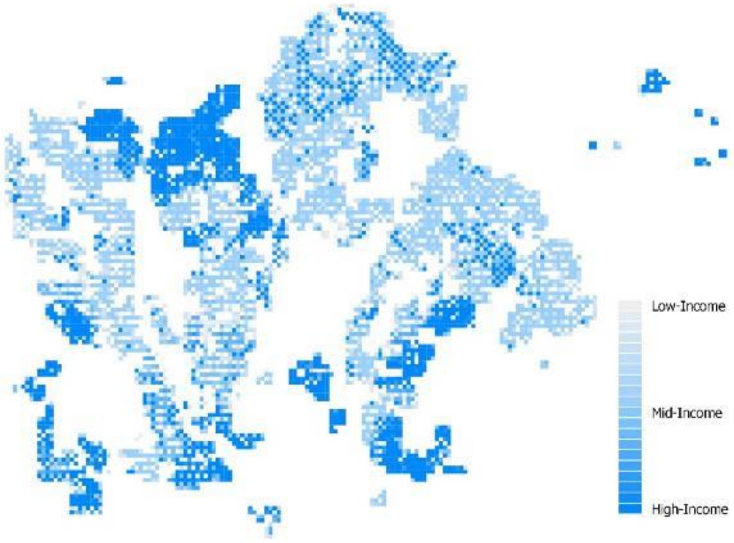
750 M

NEIGHBOURHOOD DISTANCE RADIUS

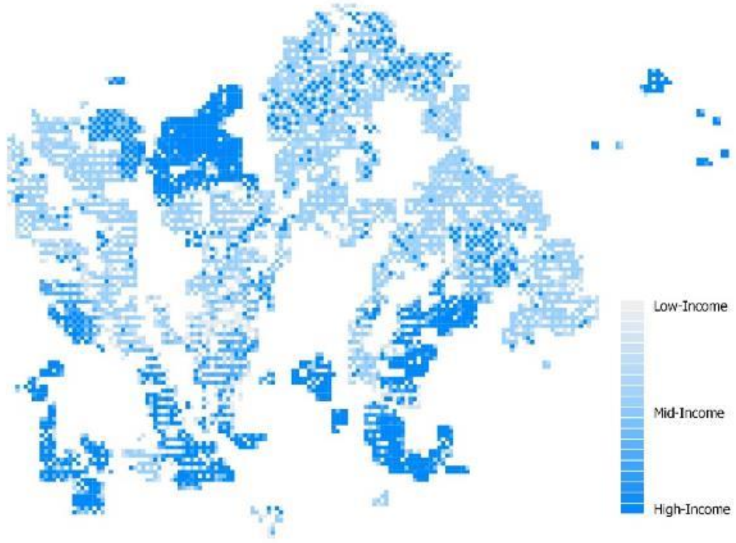
Results
45% Preference for like-neighbours



250 M



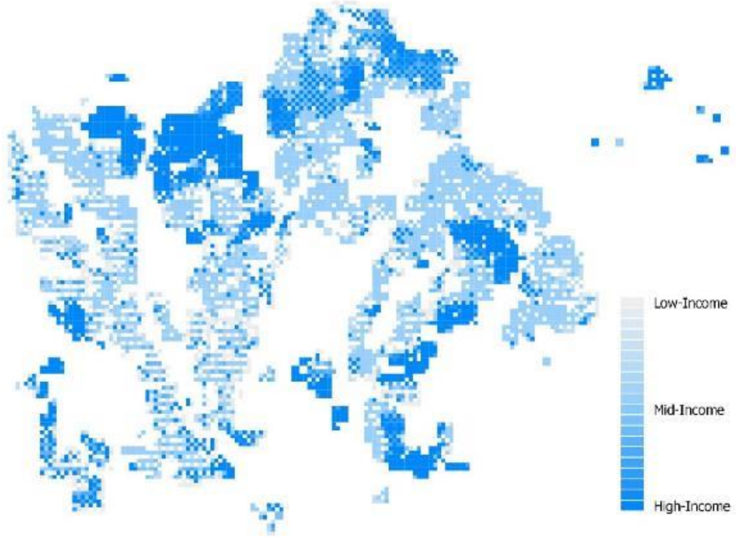
500 M



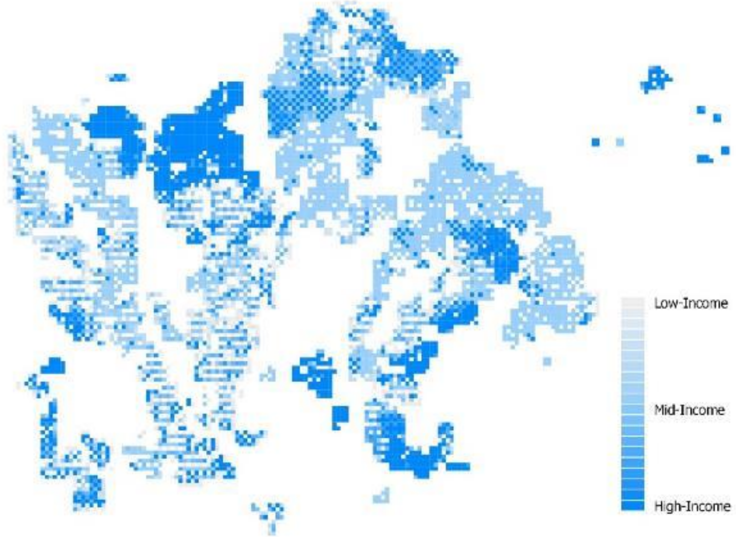
750 M

NEIGHBOURHOOD DISTANCE RADIUS

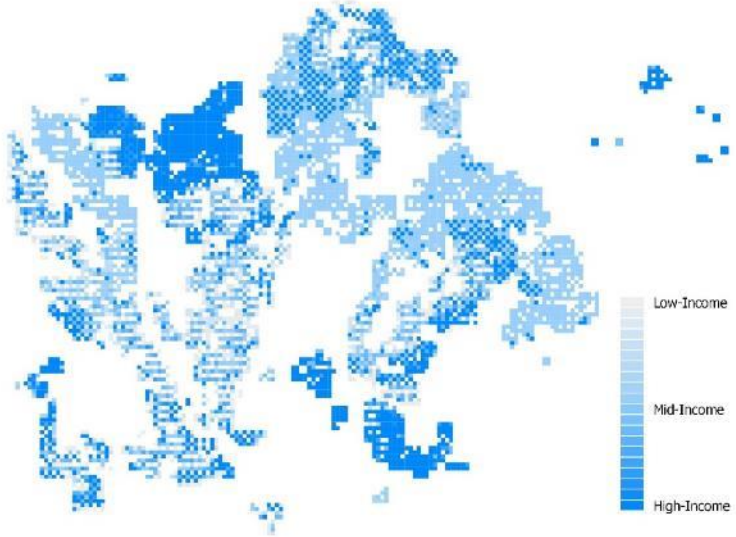
Results
60% Preference for like-neighbours



250 M



500 M

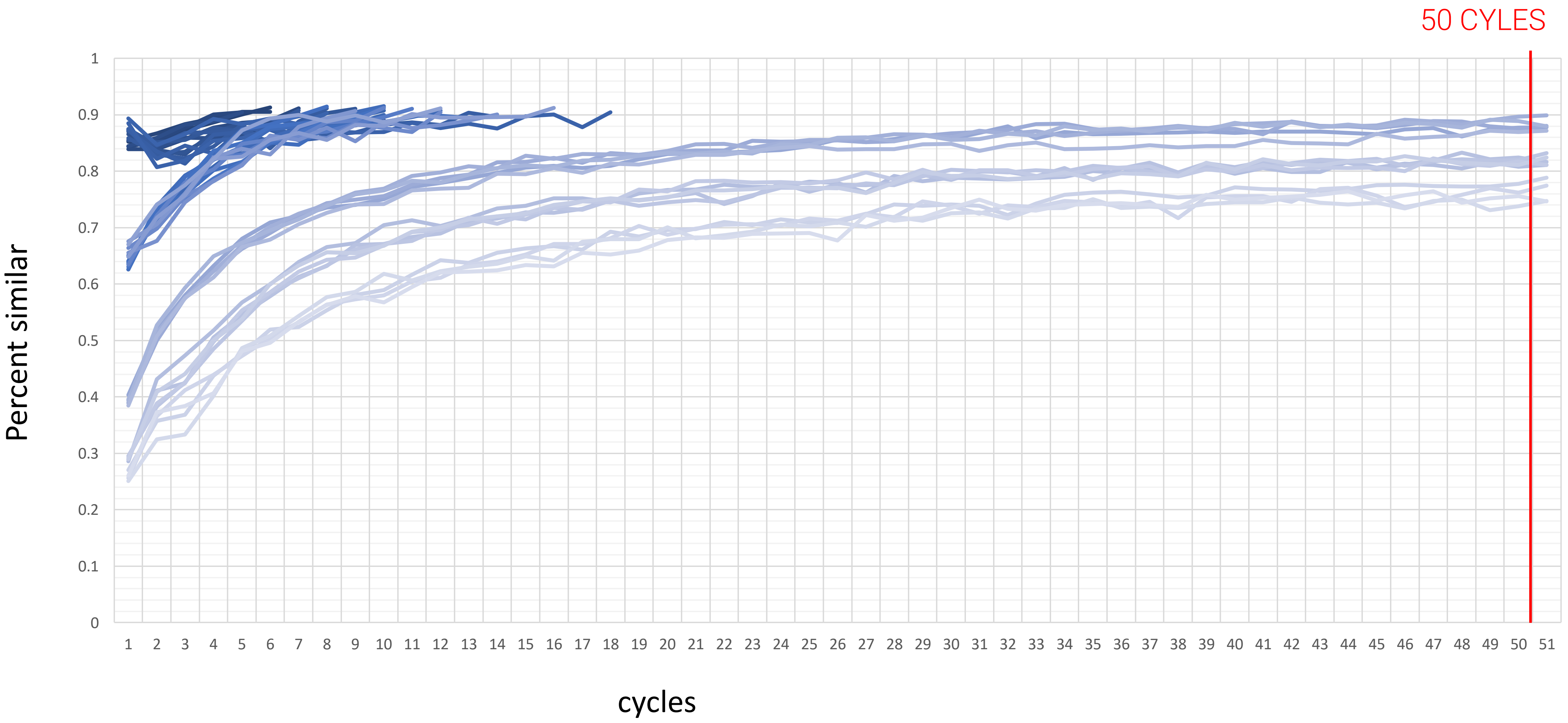


750 M

NEIGHBOURHOOD DISTANCE RADIUS

Results - Data

Simulation was stopped once 90% of agents are satisfied OR 50 cycles



Questions?

EXTENDING THE WORK INTO A THESIS

Background

- There are many factors which can influence residential segregation, including the supply and structure of housing, discrimination in the housing market, labour markets, welfare systems etc.
- Schelling demonstrated that segregation can also be produced entirely through bottom-up processes and individual preferences in the absence of these other forces
- Social distance dynamics / Social homophily
    - Similarly-disposed individuals are more likely to gather in physical (and virtual) space

- European literature suggested three sorting variables: **socio-economic status, cultural capital and ethnicity/language.**

Main Objective

Build a geospatial model of the Helsinki Metropolitan Area using empirical data

Research Questions

- Is the uncoordinated mobility of individual households, acting entirely upon assumed residential preferences for similar neighbours, capable of producing residential segregation in a realistic urban area?

➔ Do the simulations produce segregation when a realistic urban area is modelled?

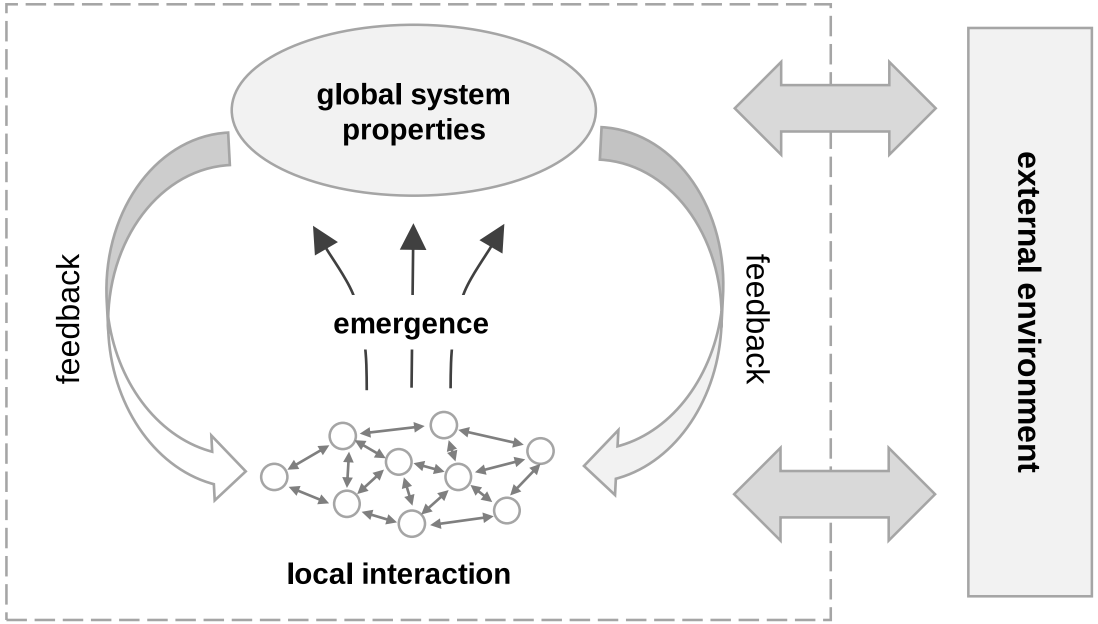
- How do simulated segregation processes vary when residential preferences are based upon different types of social homophily; namely income, education level, and language group?

➔ Testing different sorting variables (types of segregation) and group sizes

- How are these segregation processes affected by increasing intensity of demand for like-neighbours in the neighbourhood and asymmetrical preferences for different groups?

➔ What happens with different preferences?

Why CAS & ABM for segregation?

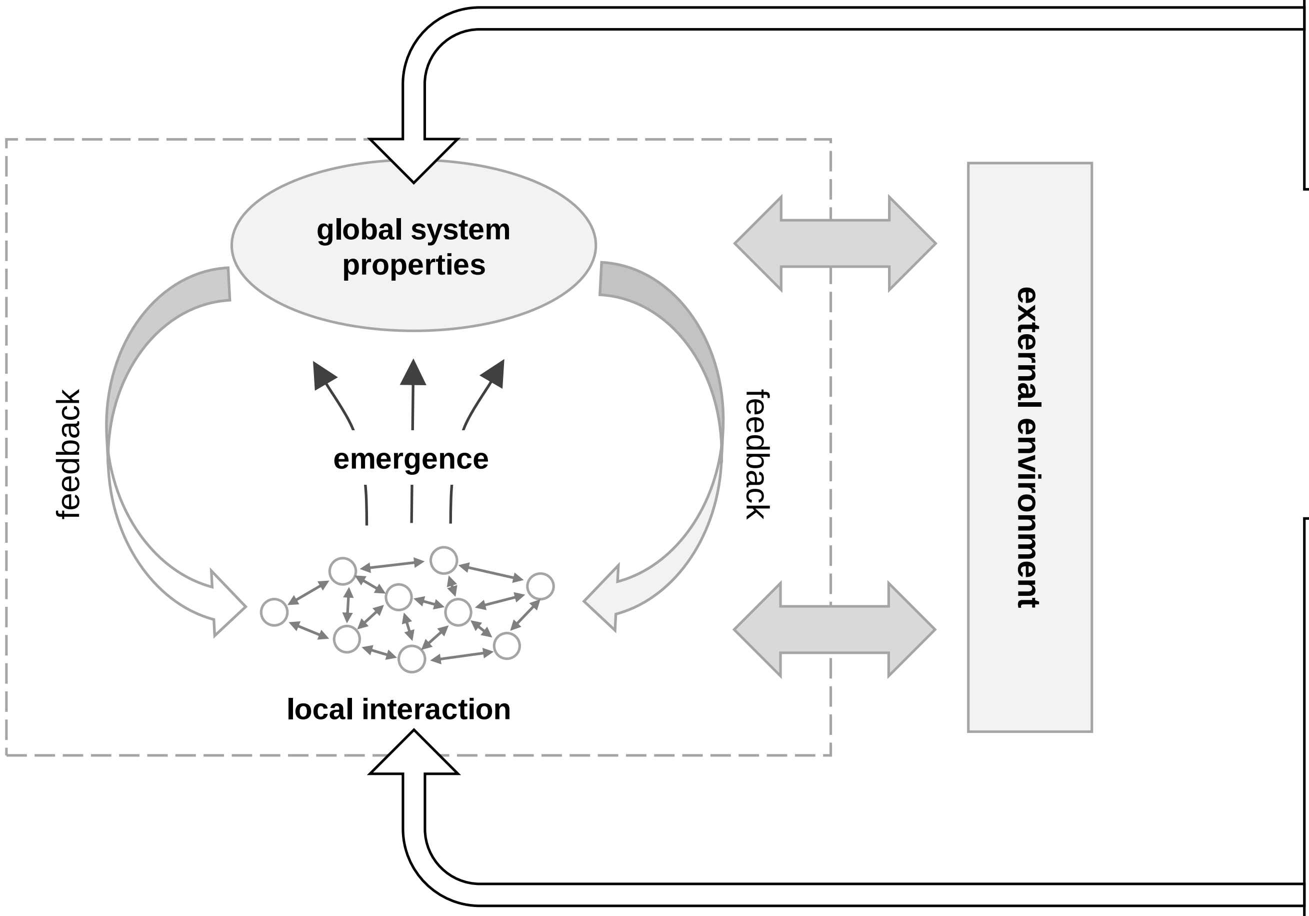


(Adapted from Adrus, 2005)

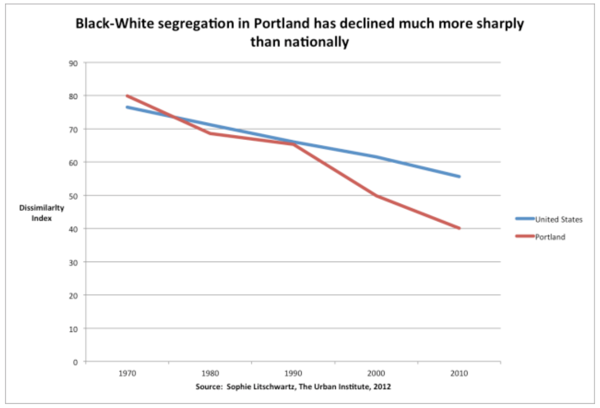
Complex properties exhibited:

- Emergence
- Interdependence
- Self-organisation
- Nonlinearity
- Path dependence

Why CAS & ABM for segregation?



a



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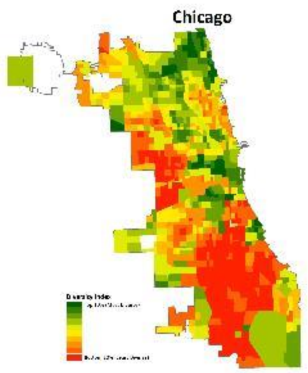


MACRO

? ← ABM IS ONE TOOL

MICRO

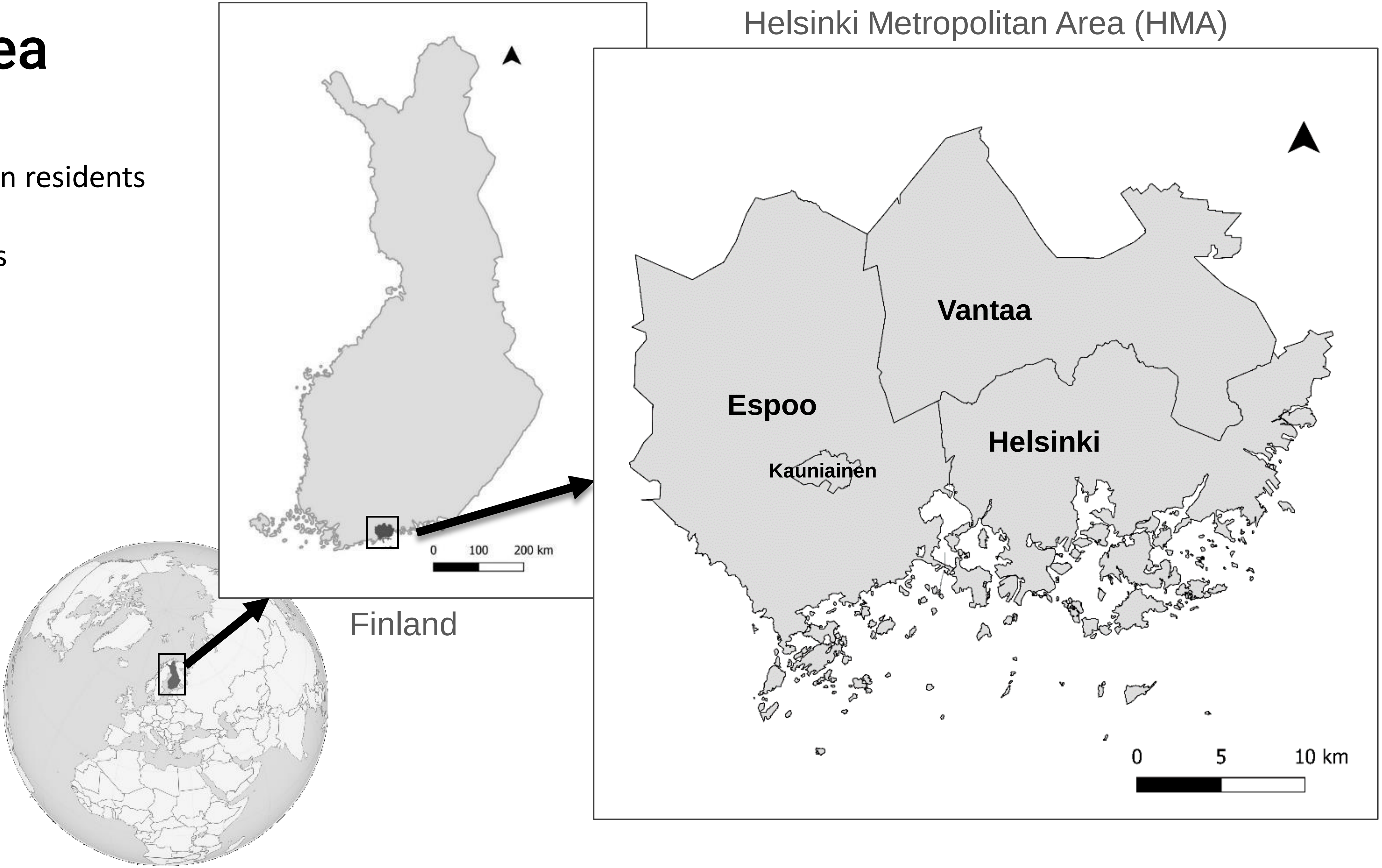
c

Neighborhood type	Neighborhood proportion of blacks	% whites willing to move into type of neighborhoods: Detroit	Atlanta	Los Angeles	Boston
	0	96.0	96.4	95.4	94.0
	0.07	87.3	87.9	93.9	91.5
	0.21	69.9	74.0	88.9	84.7
	0.36	42.7	50.4	73.4	61.6
	0.57	29.0	32.1	58.6	45.7

a) https://cityobservatory.org/most_segregated/
b) https://ggwash.org/view/36837/a-city-can-be-diverse-but-its-neighborhoods-may-still-not-be-and-dc-scores-poorly-on-both-measures
c) Xie, Y., & Zhou, X. (2012)

Study Area

- Circa 1.1 million residents
- 100,000 agents



Data

Table 4 - List of geospatial variables and attributes used for modelling

Variables	**Attributes**	**Source**
Language	Finnish mother tongue Swedish mother tongue Other mother tongue (not Finnish or Swedish)	HSY SeutuData 2019
Socio-economic	Low-income household (income deciles 1-2) Medium-income household (income deciles 3-8) High-income Household (income deciles 9-10)	Statistics Finland Grid Database, 2019
Cultural Capital	Basic Education only Matriculation Exam / Vocational Training University Education (Bachelor level or higher)	Statistics Finland Grid Database, 2019

- Income groups are calculated at a household level
- Educational attainment is recorded for all individuals over 18 years.
- Mother tongue is recorded for all individuals in the HMA.

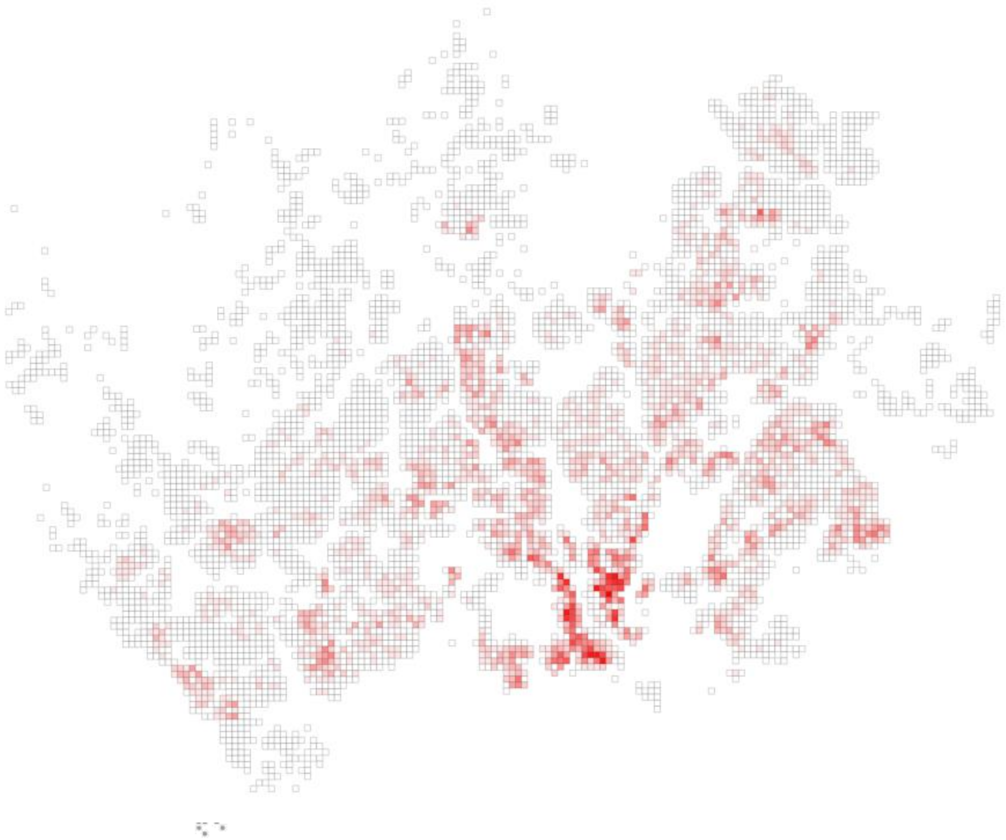
Data processing – Creating Agents

For each cell:
Multiply the total number for each group by a conversion factor to arrive at a total of 100,000 agents

Group proportions thus remain consistent with the actual regional population, and the geographic spread is accurately reflected

Density is reflected

Data processing – Creating Agents



Total agents created by sorting variable, compared to HMA population

	HMA Population		Agents Created	
	Number	%	Number	%
Education groups				
Basic education	196,298	*21%*	21,313	*21%*
Secondary education	394,447	*43%*	42,967	*43%*
Tertiary education	328,721	*36%*	35,791	*36%*
*Individuals aged over 18**	*919,466*		*100,071*	
Income groups				
Low-income	108,283	*20%*	19,491	*19%*
Medium-income	296,129	*53%*	53,429	*53%*
High-income	150,516	*27%*	27,190	*27%*
*Total households**	*554,928*		*100,110*	
Language groups				
Finnish	915,647	*77%*	77,222	*78%*
Swedish	65,468	*5%*	5,281	*5%*
Other	213,526	*18%*	16,916	*17%*
*Total individuals**	*1,194,641*		*99,419*	

Defining Scenarios to be tested

The scenarios are as follows:

- ***Scenario A***: 30% preference for co-group neighbours for all groups.
- ***Scenario B***: 50% preference for co-group neighbours for all groups.
- ***Scenario C:*** 70% preference for one group, and 30% preference for both other groups.

  Higher 70% threshold applied to:

  - high-income agents (high economic capital),
  - agents with tertiary education (high cultural capital)
  - agents with Finnish as a mother tongue (large majority group).

	Percentage of neighbours		
	Scenario A	Scenario B	Scenario C
Education groups			
Basic education	30%	50%	30%
Secondary education	30%	50%	30%
Tertiary education	30%	50%	70%
Income groups			
Low income	30%	50%	30%
Medium income	30%	50%	30%
High income	30%	50%	70%
Language groups			
Finnish	30%	50%	70%
Swedish	30%	50%	30%
Other	30%	50%	30%

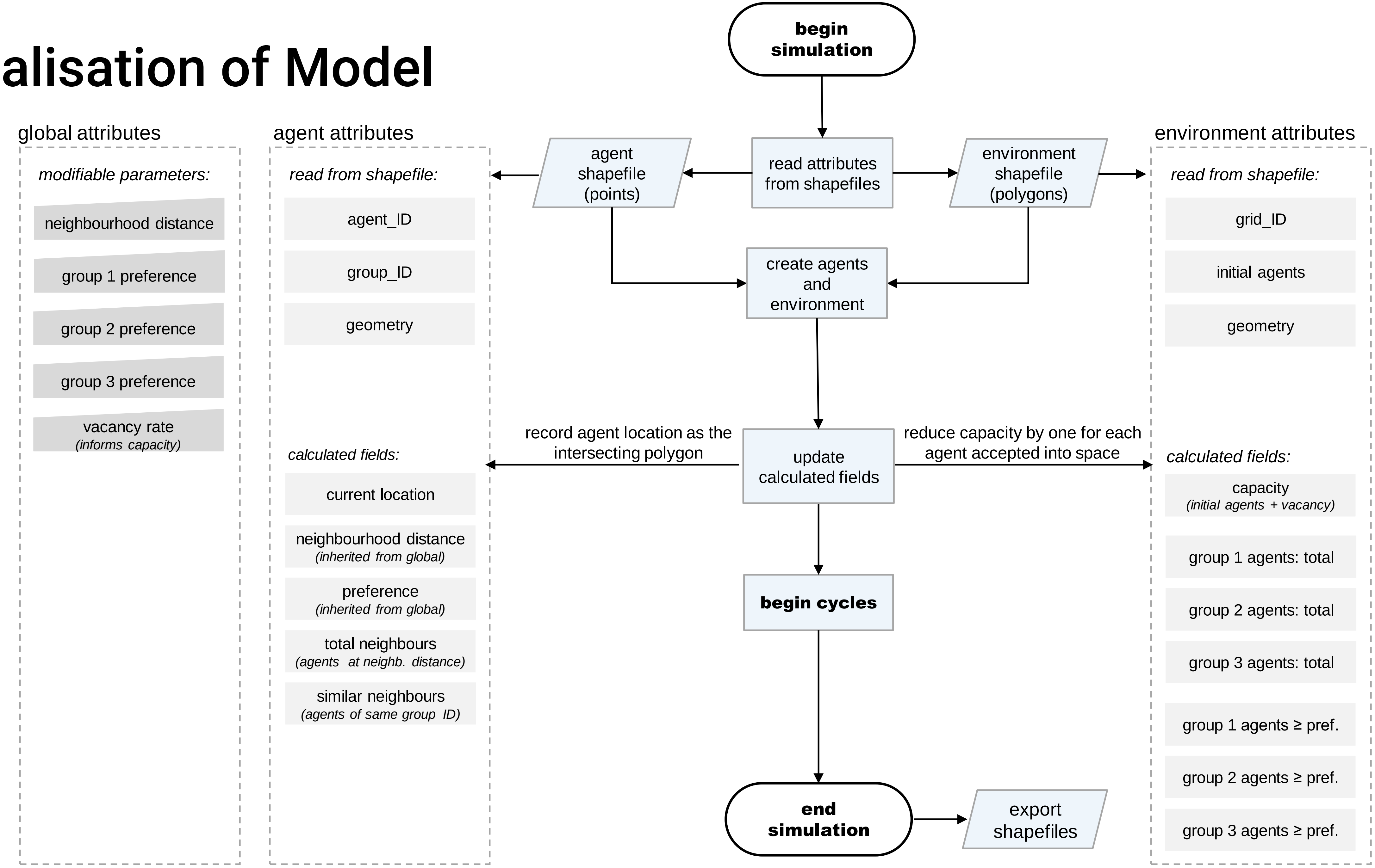
Rules of interaction

- Each cycle agents will move, when possible, from areas where the population composition of their neighbourhood does not meet the prescribed preference threshold for similar (co-group) neighbours to a new location.

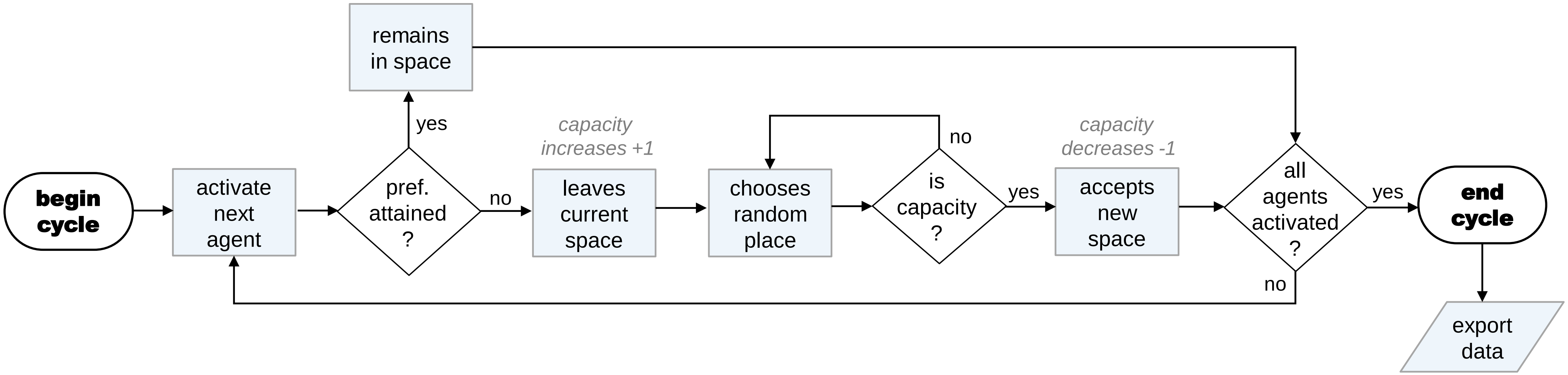
- Agents have perfect information about the composition of their current neighbourhood, but no information about areas outside their neighbourhood. New locations are chosen at random, and the agent will assess the neighbourhood composition only on the next cycle

- If a chosen location does not have remaining capacity, the agent chooses a new location.

Initialisation of Model



Migration process each cycle

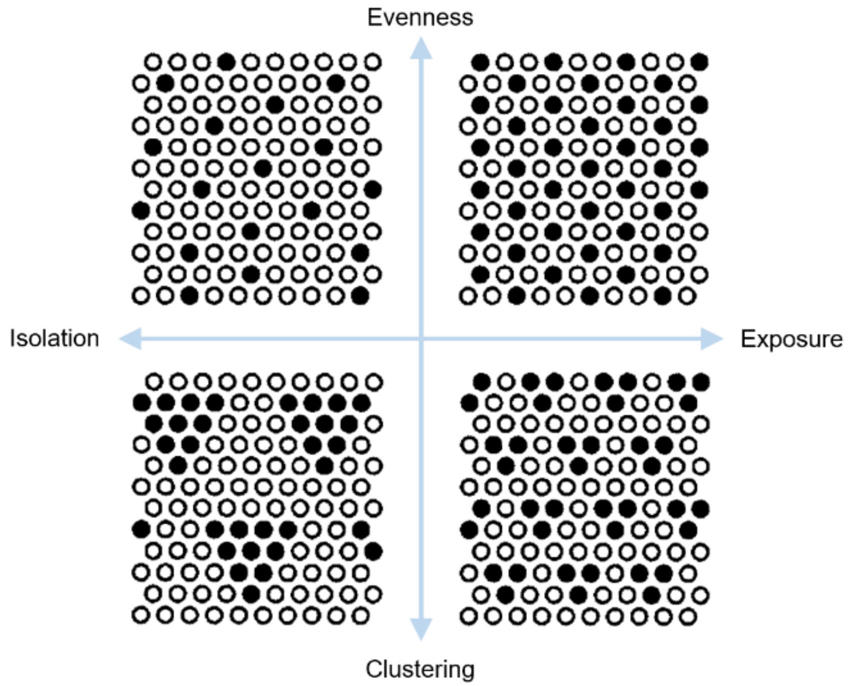


Data Analysis

For each Scenario and each grouping variable

- Export data at the end of each cycle (20 cycles per simulation)
- Repeat each simulation 10 times (batch processing - different seed)
- Aggregate the values of the 10 simulations when calculating segregation measures
- Track the progress over iterations (through time)

Measuring segregation



Reardon, S.F. and O'Sullivan, D. (2004), Measures of Spatial Segregation. Sociological Methodology, 34: 121-162. https://doi.org/10.1111/j.0081-1750.2004.00150.x

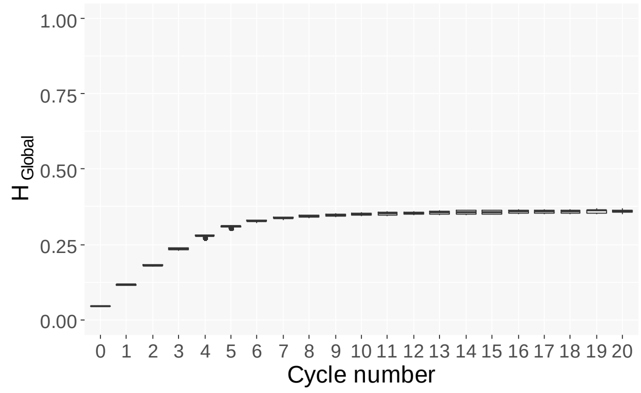
Spatial evenness
Are the groups evenly distributed according to the global composition?

Spatial Information Theory Index (H)

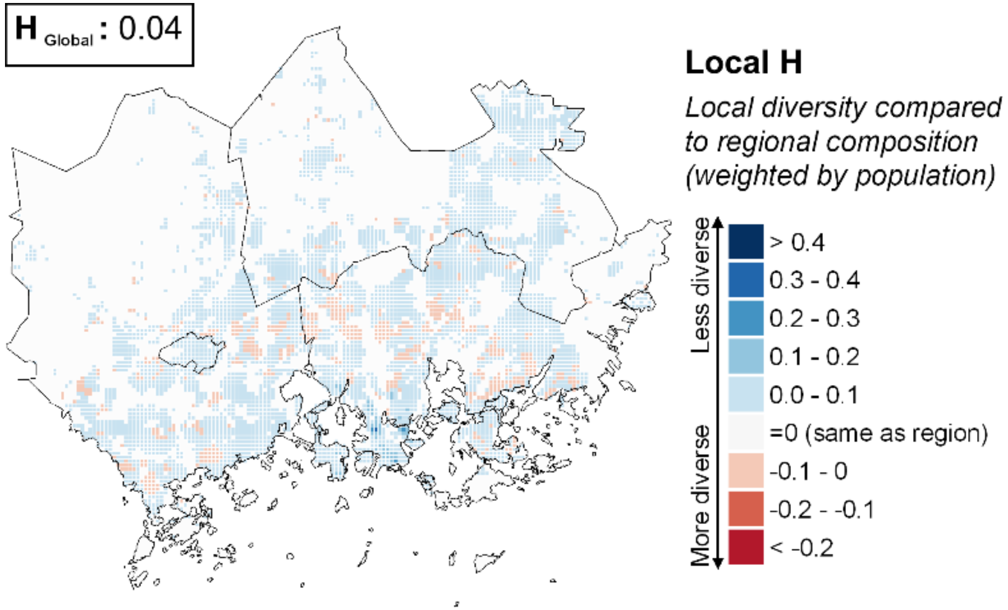
Spatial Isolation
Potential for interaction (chance of living in the same areal unit)

Spatial Isolation Index (Q_m)

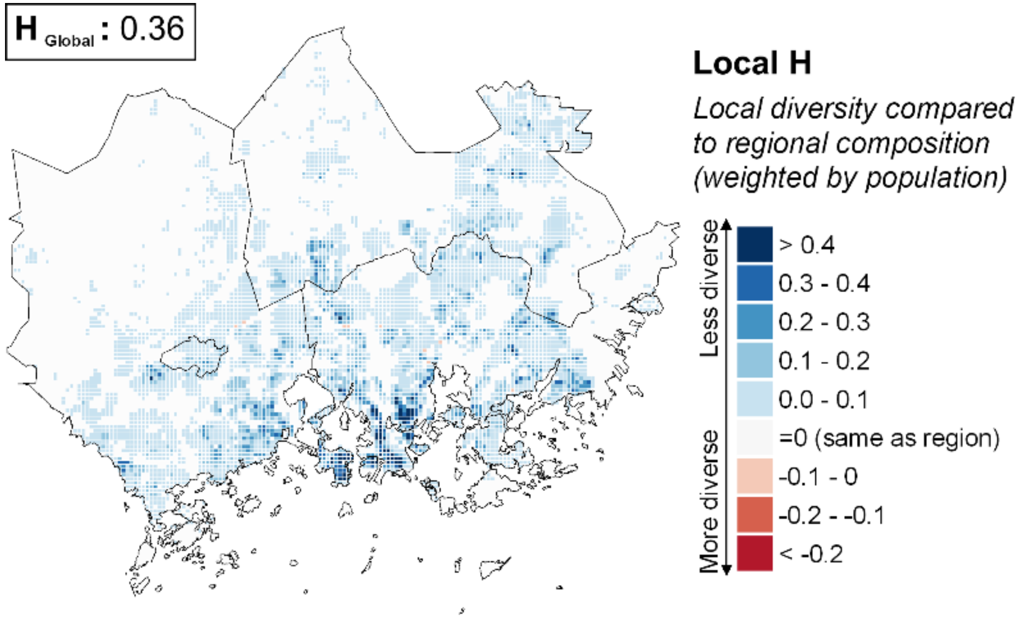
Measuring segregation - Evenness



Example: Educational attainment (30% preference)

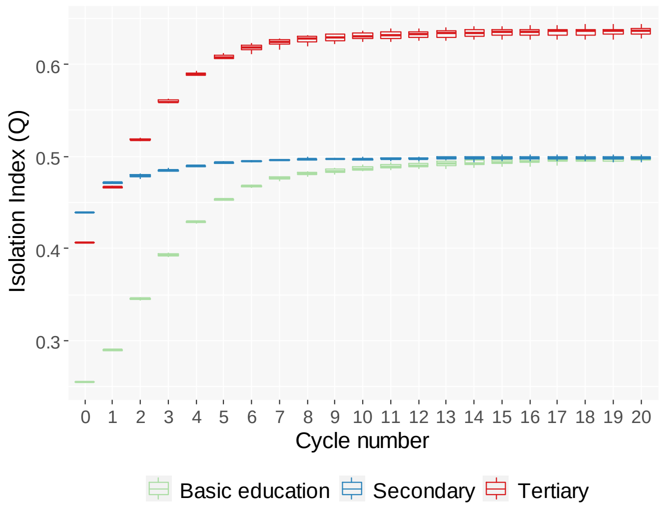


Educational attainment: Baseline



Educational attainment: After 20 cycles (30% preference)

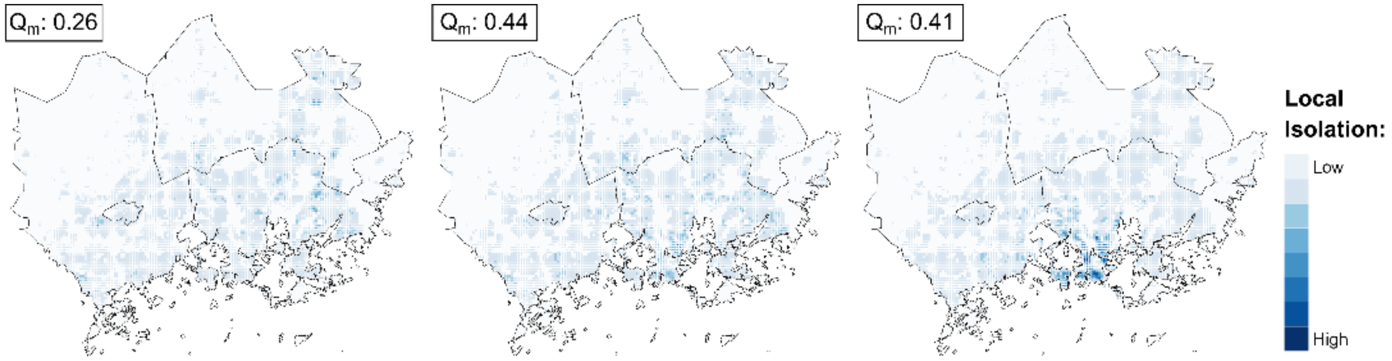
Measuring segregation – Isolation



Example: Educational attainment (30% preference)

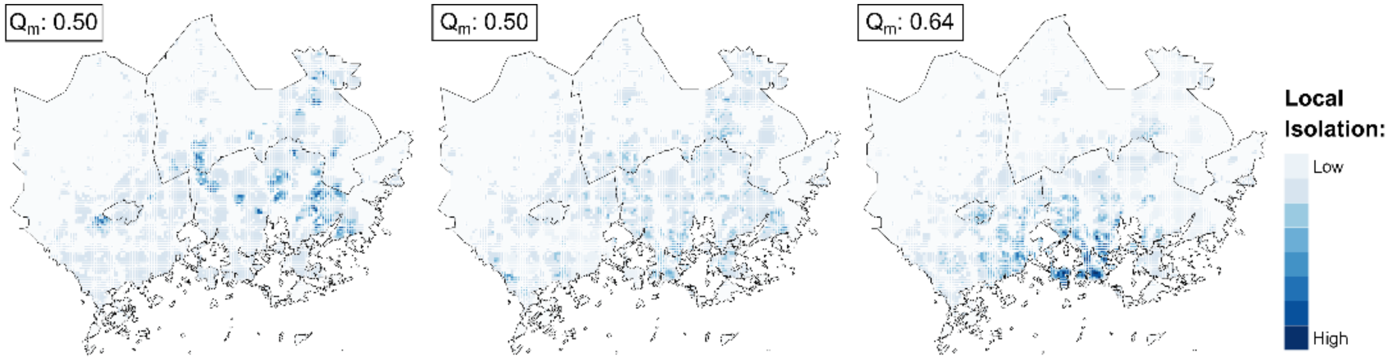
Basic education *Secondary education* *Tertiary education*

Baseline



Basic education *Secondary education* *Tertiary education*

After 20 cycles



Results

Table 7 - Summary of simulation results after 20 cycles.

Each scenario was run 10 times, and the mean aggregate values reported.

	Baseline measures	Scenario A 30% pref	Scenario B 50% pref	Scenario C 30/70% pref
Education groups				
$\tilde{H}$ - *Global*	0.04	0.36	0.56	0.25
$\tilde{Q}$ - *Basic education*	0.26	0.50	0.57	0.41
$\tilde{Q}$ - *Secondary education*	0.44	0.50	0.80	0.49
$\tilde{Q}$ - *Tertiary education**	0.41	0.64	0.78	0.57
Income groups				
$\tilde{H}$ - *Global*	0.06	0.26	0.74	0.14
$\tilde{Q}$ - *Low-income*	0.24	0.35	0.70	0.31
$\tilde{Q}$ - *Medium-income*	0.55	0.59	0.91	0.58
$\tilde{Q}$ - *High-income**	0.34	0.53	0.93	0.39
Language groups				
$\tilde{H}$ - *Global*	0.08	0.08	0.15	0.81
$\tilde{Q}$ - *Finnish **	0.79	0.79	0.82	0.97
$\tilde{Q}$ - *Swedish*	0.11	0.08	0.08	0.74
$\tilde{Q}$ - *Other*	0.25	0.25	0.37	0.85

** Assigned the higher 70% preference in Scenario C*

Results: 50% preference

Education groups – Scenario B (50%)

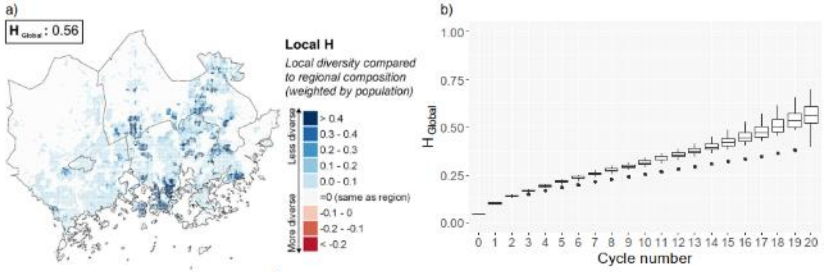


Figure 34 - Information theory index ($\bar{H}$) for education groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{H}$ values as mapped (a) is equal to the global $\bar{H}$ value. Local values are multiplied by 1000 in the legend. Simulations were repeated 10 times and the evolution of the global $\bar{H}$ values over the 20 cycles reported (b).

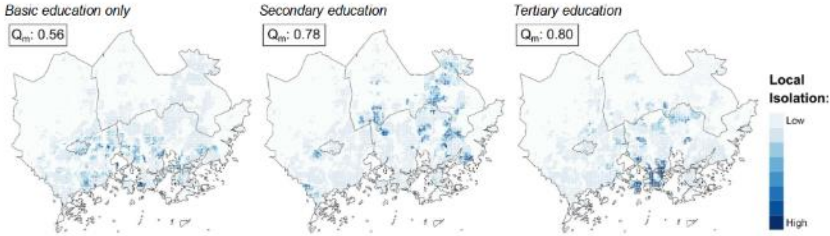


Figure 35 - Global and local isolation index ($\bar{Q}_m$) for education groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{Q}_m$ values as mapped is equal to the global $\bar{Q}_m$ figure indicated above each map. As the calculation of $\bar{Q}_m$ considers the overall proportions of each group in the region, it cannot be directly compared across groups, but can be compared to their baseline.

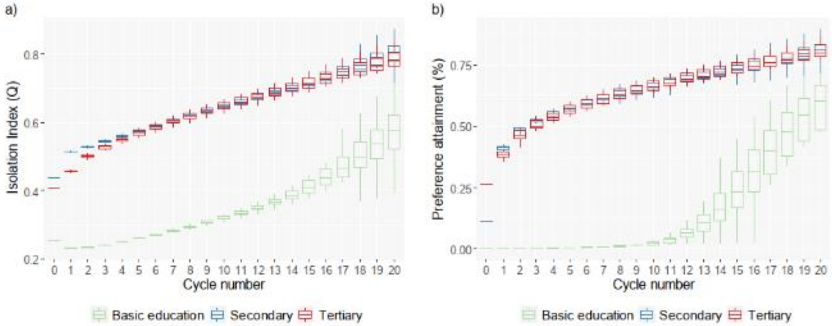


Figure 36 - Evolution of the isolation index ($\bar{Q}_m$) for education groups with 50% preference thresholds (a) and the proportion of agents which are attaining their preference threshold for same-group neighbours (b). 10 simulations were run to account for the stochastic nature of the model, the aggregate results are presented here as a box plot.

Language groups – Scenario B (50%)

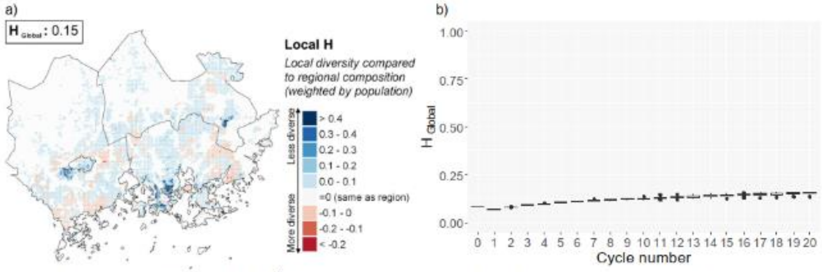


Figure 37 - Information theory index ($\bar{H}$) for language groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{H}$ values as mapped (a) is equal to the global $\bar{H}$ value. Local values are multiplied by 1000 in the legend. Simulations were repeated 10 times and the evolution of the global $\bar{H}$ values over the 20 cycles reported (b).

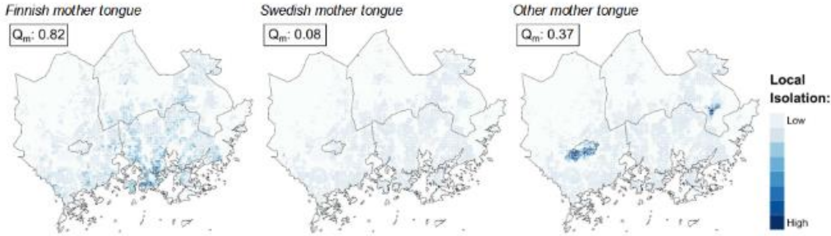


Figure 38 - Global and local isolation index ($\bar{Q}_m$) for language groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{Q}_m$ values as mapped is equal to the global $\bar{Q}_m$ figure indicated above each map. As the calculation of $\bar{Q}_m$ considers the overall proportions of each group in the region, it cannot be directly compared across groups, but can be compared to their baseline.

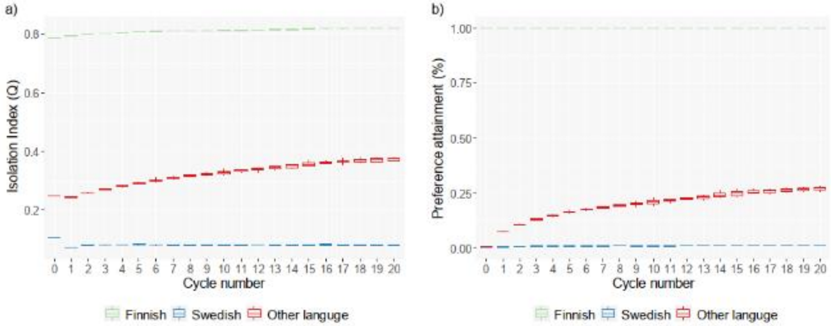


Figure 39 - Evolution of the isolation index ($\bar{Q}_m$) for language groups with 50% preference thresholds (a) and the proportion of agents which are attaining their preference threshold for same-group neighbours (b). 10 simulations were run to account for the stochastic nature of the model, the aggregate results are presented here as a box plot.

Income groups – Scenario B (50%)

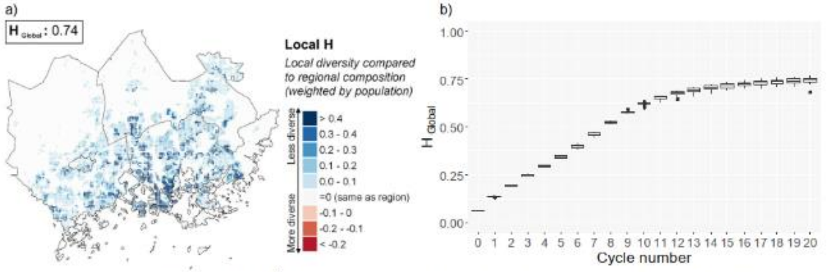


Figure 31 - Information theory index ($\bar{H}$) for income groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{H}$ values as mapped (a) is equal to the global $\bar{H}$ value. Local values are multiplied by 1000 in the legend. Simulations were repeated 10 times and the evolution of the global $\bar{H}$ values over the 20 cycles reported (b).

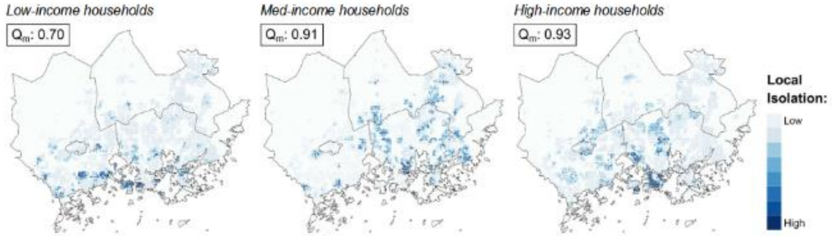


Figure 32 - Global and local isolation index ($\bar{Q}_m$) for income groups with 50% preference thresholds after 20 cycles. The sum of the local $\bar{Q}_m$ values as mapped is equal to the global $\bar{Q}_m$ figure indicated above each map. As the calculation of $\bar{Q}_m$ considers the overall proportions of each group in the region, it cannot be directly compared across groups, but can be compared to their baseline.

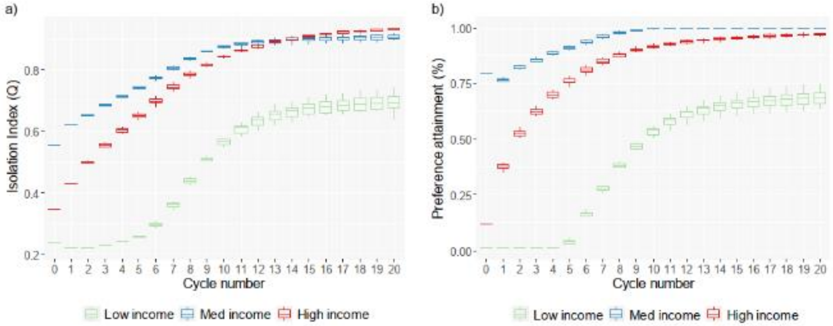


Figure 33 - Evolution of the isolation index ($\bar{Q}_m$) for income groups with 50% preference thresholds (a) and the proportion of agents which are attaining their preference threshold for same-group neighbours (b). 10 simulations were run to account for the stochastic nature of the model, the aggregate results are presented here as a box plot.

ASSUMPTIONS, SIMPLICATIONS AND LIMITATIONS

- All models are necessarily simplifications of reality
- Important to discuss and make clear these simplifications and assumptions
- The process of creating rule-sets is useful in questioning concepts and processes (e.g. what is a neighbourhood?)

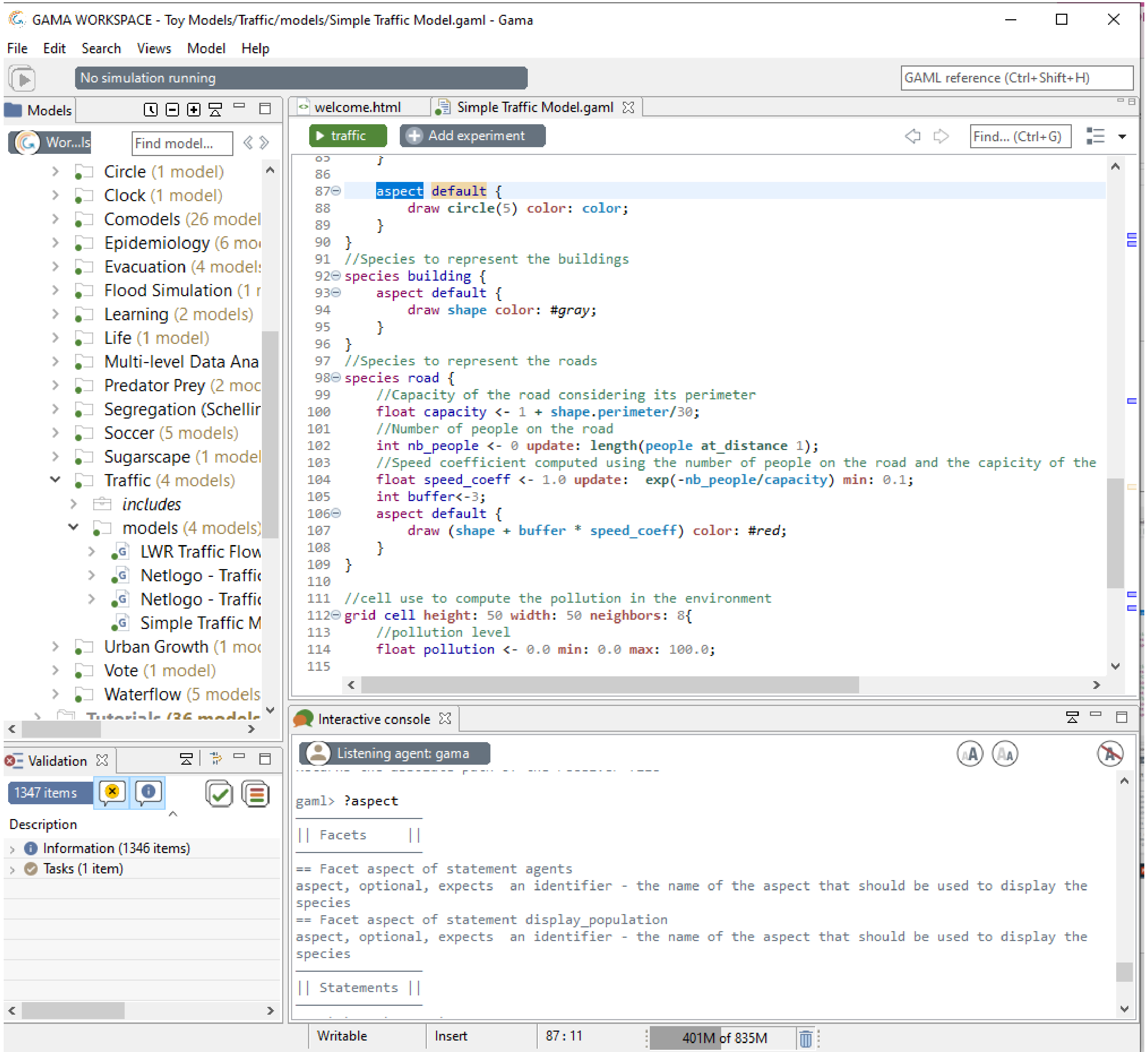
Questions?

TIPS FOR USING GAMA + GENERAL CODING

Finding Help

If you can't find the answer on GAMA-platform website, try google:

- 'search term' + gama-platform
- ? + 'search term' in GAMA interactive console
  - E.g. ?aspect



Comment your code

```
// set the agent's location as the centroid of the grid cell
location of one_people <- centroid(shape);
```

1. **Code descriptions make it easier to understand your code**.

2. **Writing code descriptions can help you debug your code**.
Going through step by step, you may find that your code doesn't actually do what you thought, and fix issues in this way.

3. **Code descriptions make it easier for other users to use and understand your code**.
Often "why" is more important than how

https://geo-python-site.readthedocs.io/en/latest/notebooks/L2/gcp-2-describing-code.html

Comment your code

`//…`	: inlined comments (always on one line)
`/* … */`	: block comments (possibly on several lines)

Document what the line is doing, and what you have learned

```
// locate the agent within the grid cell
location of one_people <- centroid(shape); // use either centroid(shape) or any_location_in(shape)
```

Isolate lines to help with debugging

```
species space{
// Create attributes for space
int surface;
// int capacity ;
int cell_id;
```

Keep old working code in the script whilst you test improvements

```
/*
reflex stop_simulation when: cycle > 20 {
do pause ;
//save [name, location, host] to: "save_data.csv" type: "csv";}
*/
```

Version control

GitHub

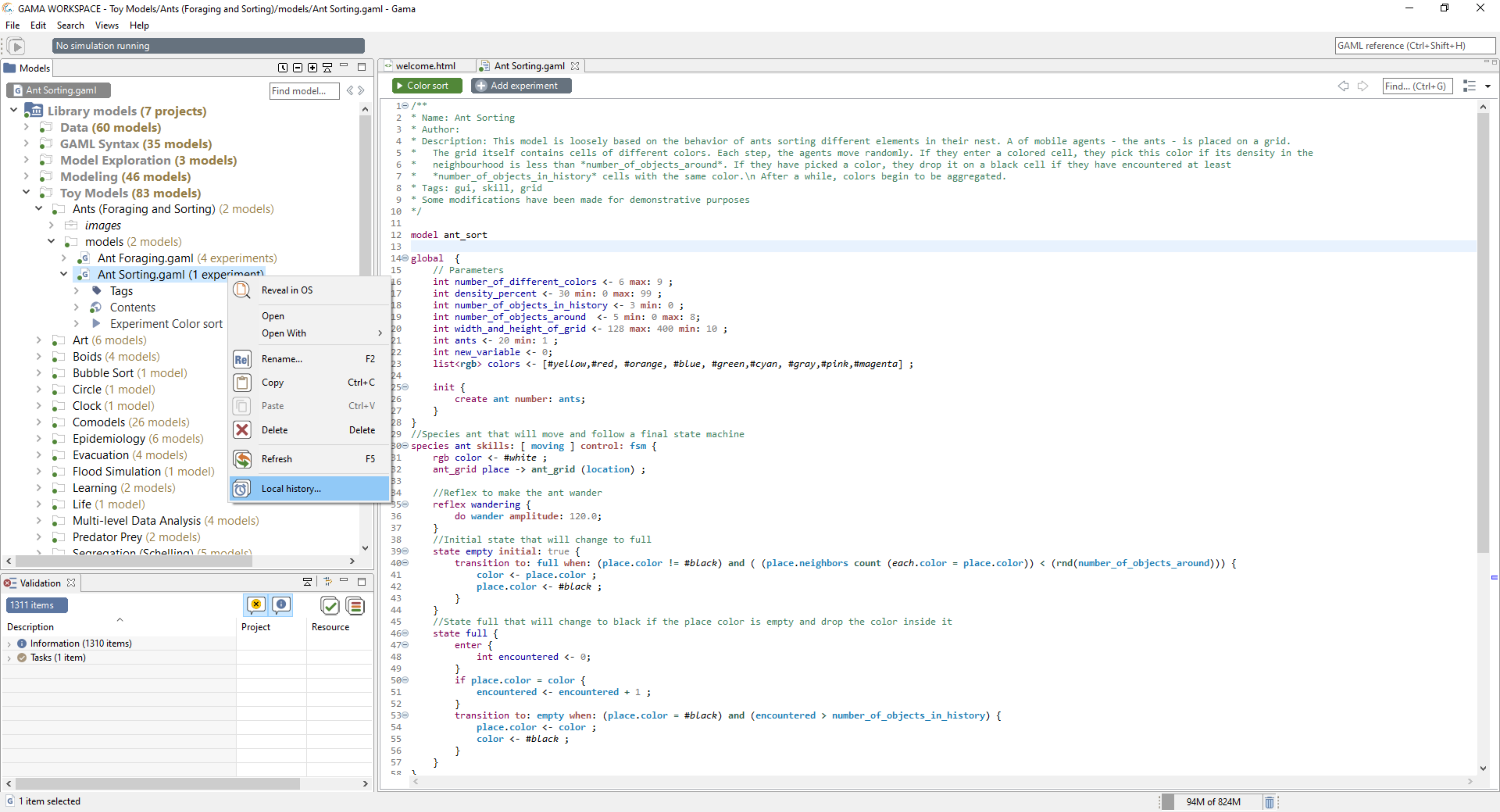
https://gama-platform.github.io/wiki/Using_Git

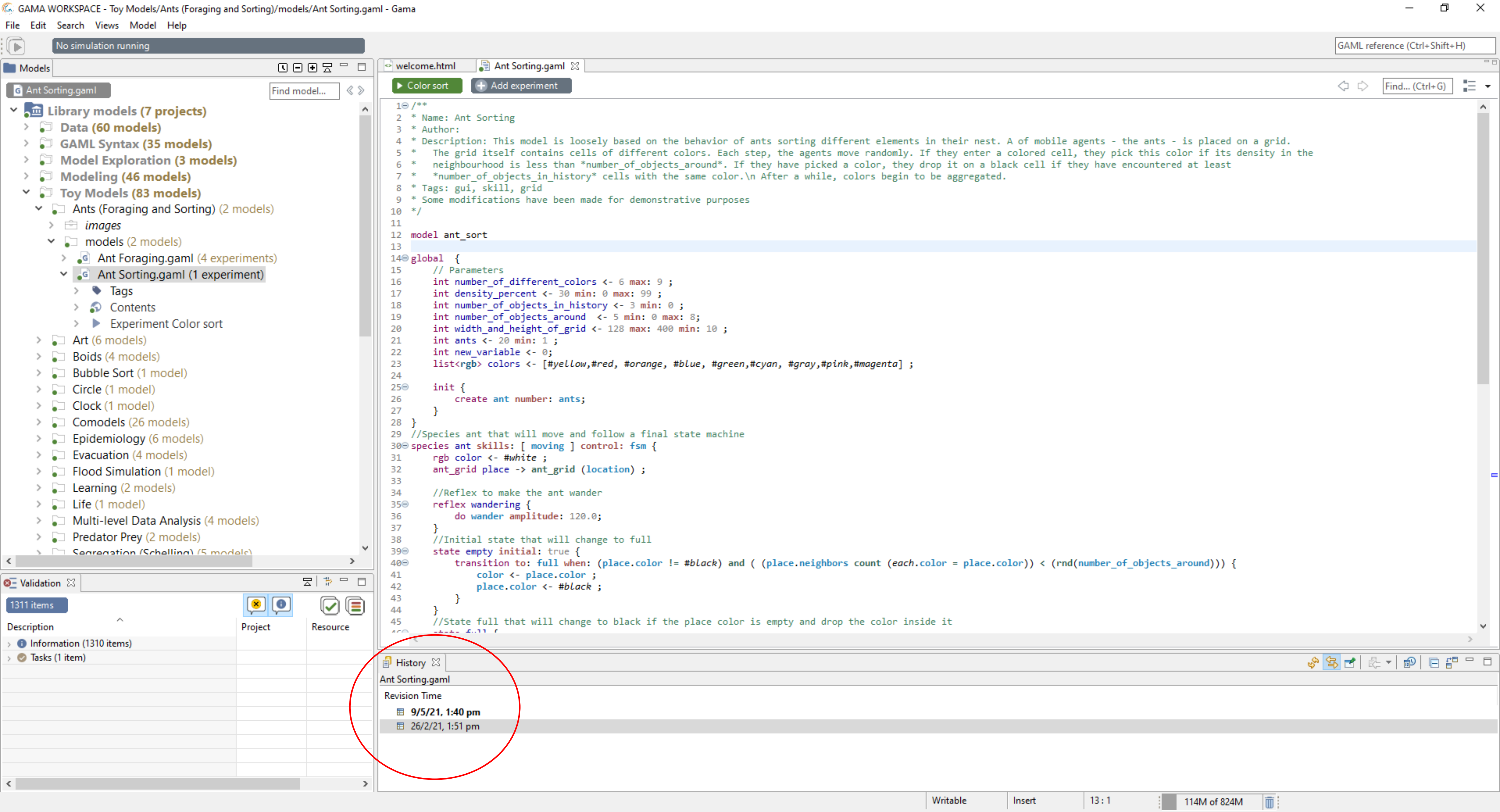
https://www.youtube.com/watch?v=fvNcYwA9Kxw

Local history in GAMA

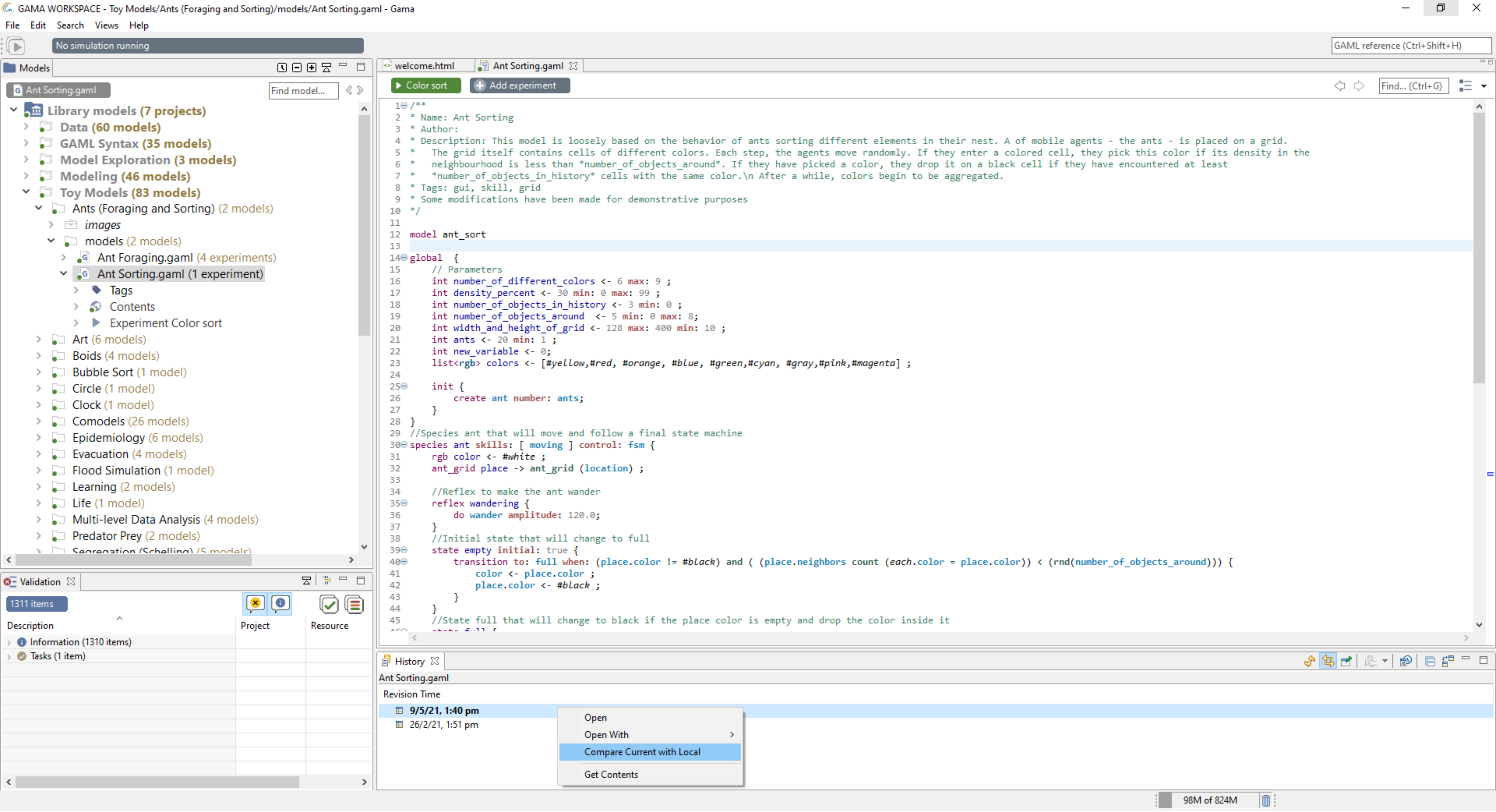
https://gama-platform.github.io/wiki/GamlEditorGeneralities#local-history

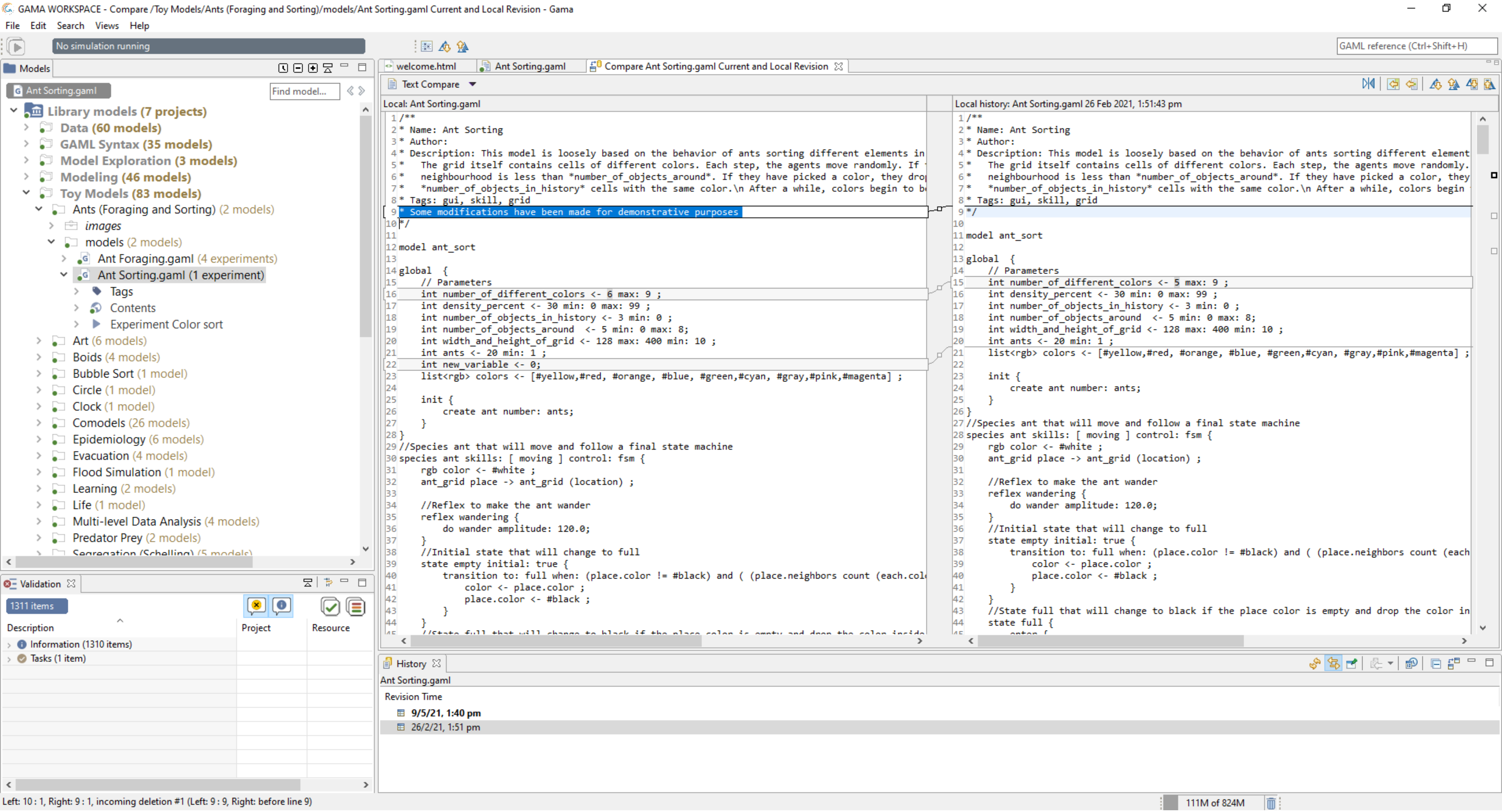
https://www.youtube.com/watch?v=kXNQJImSwBQ


GAMA WORKSPACE - Toy Models/Ants (Foraging and Sorting)/models/Ant Sorting.gaml - Gama
File Edit Search Views Help
No simulation running
GAML reference (Ctrl+Shift+H)
Models
Ant Sorting.gaml
Find model...
Library models (7 projects)
Data (60 models)
GAML Syntax (35 models)
Model Exploration (3 models)
Modeling (46 models)
Toy Models (83 models)
Ants (Foraging and Sorting) (2 models)
images
models (2 models)
Ant Foraging.gaml (4 experiments)
Ant Sorting.gaml (1 experiment)
Tags
Contents
Experiment Color sort
Art (6 models)
Boids (4 models)
Bubble Sort (1 model)
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
Reveal in OS
Open
Open With
Rename... F2
Copy Ctrl+C
Paste Ctrl+V
Delete Delete
Refresh F5
Local history...
Validation
1311 items
Description
Project
Resource
Information (1310 items)
Tasks (1 item)
1 item selected
welcome.html
Ant Sorting.gaml
Color sort
Add experiment
Find... (Ctrl+G)
/**
* Name: Ant Sorting
* Author:
* Description: This model is loosely based on the behavior of ants sorting different elements in their nest. A of mobile agents - the ants - is placed on a grid.
* The grid itself contains cells of different colors. Each step, the agents move randomly. If they enter a colored cell, they pick this color if its density in the
* neighbourhood is less than *number_of_objects_around*. If they have picked a color, they drop it on a black cell if they have encountered at least
* *number_of_objects_in_history* cells with the same color.\n After a while, colors begin to be aggregated.
* Tags: gui, skill, grid
* Some modifications have been made for demonstrative purposes
*/
model ant_sort
global {
// Parameters
int number_of_different_colors <- 6 max: 9 ;
int density_percent <- 30 min: 0 max: 99 ;
int number_of_objects_in_history <- 3 min: 0 ;
int number_of_objects_around <- 5 min: 0 max: 8;
int width_and_height_of_grid <- 128 max: 400 min: 10 ;
int ants <- 20 min: 1 ;
int new_variable <- 0;
list<rgb> colors <- [#yellow,#red, #orange, #blue, #green,#cyan, #gray,#pink,#magenta] ;
init {
create ant number: ants;
}
}
//Species ant that will move and follow a final state machine
species ant skills: [moving] control: fsm {
rgb color <- #white ;
ant_grid place -> ant_grid (location) ;
//Reflex to make the ant wander
reflex wandering {
do wander amplitude: 120.0;
}
//Initial state that will change to full
state empty initial: true {
transition to: full when: (place.color != #black) and ((place.neighbors count (each.color = place.color)) < (rnd(number_of_objects_around))) {
color <- place.color ;
place.color <- #black ;
}
}
//State full that will change to black if the place color is empty and drop the color inside it
state full {
enter {
int encountered <- 0;
}
if place.color = color {
encountered <- encountered + 1 ;
}
transition to: empty when: (place.color = #black) and (encountered > number_of_objects_in_history) {
place.color <- color ;
color <- #black ;
}
}
94M of 824M



GAMA WORKSPACE - Toy Models/Ants (Foraging and Sorting)/models/Ant Sorting.gaml - Gama
File Edit Search Views Model Help
No simulation running
GAML reference (Ctrl+Shift+H)
Models
Ant Sorting.gaml
Find model...
Library models (7 projects)
Data (60 models)
GAML Syntax (35 models)
Model Exploration (3 models)
Modeling (46 models)
Toy Models (83 models)
Ants (Foraging and Sorting) (2 models)
images
models (2 models)
Ant Foraging.gaml (4 experiments)
Ant Sorting.gaml (1 experiment)
Tags
Contents
Experiment Color sort
Art (6 models)
Boids (4 models)
Bubble Sort (1 model)
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
Segregation (Schelling) (5 models)
Validation
1311 items
Description
Project
Resource
Information (1310 items)
Tasks (1 item)
welcome.html
Ant Sorting.gaml
Color sort
Add experiment
Find... (Ctrl+G)
/**
* Name: Ant Sorting
* Author:
* Description: This model is loosely based on the behavior of ants sorting different elements in their nest. A of mobile agents - the ants - is placed on a grid.
*   The grid itself contains cells of different colors. Each step, the agents move randomly. If they enter a colored cell, they pick this color if its density in the
*   neighbourhood is less than *number_of_objects_around*. If they have picked a color, they drop it on a black cell if they have encountered at least
*   *number_of_objects_in_history* cells with the same color.\n After a while, colors begin to be aggregated.
* Tags: gui, skill, grid
* Some modifications have been made for demonstrative purposes
*/
model ant_sort
global {
// Parameters
int number_of_different_colors <- 6 max: 9 ;
int density_percent <- 30 min: 0 max: 99 ;
int number_of_objects_in_history <- 3 min: 0 ;
int number_of_objects_around <- 5 min: 0 max: 8;
int width_and_height_of_grid <- 128 max: 400 min: 10 ;
int ants <- 20 min: 1 ;
int new_variable <- 0;
list<rgb> colors <- [#yellow,#red, #orange, #blue, #green,#cyan, #gray,#pink,#magenta] ;
init {
create ant number: ants;
}
}
//Species ant that will move and follow a final state machine
species ant skills: [moving] control: fsm {
rgb color <- #white ;
ant_grid place -> ant_grid (location) ;
//Reflex to make the ant wander
reflex wandering {
do wander amplitude: 120.0;
}
//Initial state that will change to full
state empty initial: true {
transition to: full when: (place.color != #black) and ((place.neighbors count (each.color = place.color)) < (rnd(number_of_objects_around))) {
color <- place.color ;
place.color <- #black ;
}
}
//State full that will change to black if the place color is empty and drop the color inside it
History
Ant Sorting.gaml
Revision Time
9/5/21, 1:40 pm
26/2/21, 1:51 pm
Writable
Insert
13 : 1
114M of 824M


GAMA WORKSPACE - Toy Models/Ants (Foraging and Sorting)/models/Ant Sorting.gaml - Gama
File Edit Search Views Help
No simulation running
GAML reference (Ctrl+Shift+H)
Models
Ant Sorting.gaml
Find model...
Library models (7 projects)
Data (60 models)
GAML Syntax (35 models)
Model Exploration (3 models)
Modeling (46 models)
Toy Models (83 models)
Ants (Foraging and Sorting) (2 models)
images
models (2 models)
Ant Foraging.gaml (4 experiments)
Ant Sorting.gaml (1 experiment)
Tags
Contents
Experiment Color sort
Art (6 models)
Boids (4 models)
Bubble Sort (1 model)
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
Validation
1311 items
Description
Project
Resource
Information (1310 items)
Tasks (1 item)
welcome.html
Ant Sorting.gaml
Color sort
Add experiment
Find... (Ctrl+G)
/**
* Name: Ant Sorting
* Author:
* Description: This model is loosely based on the behavior of ants sorting different elements in their nest. A of mobile agents - the ants - is placed on a grid.
* The grid itself contains cells of different colors. Each step, the agents move randomly. If they enter a colored cell, they pick this color if its density in the
* neighbourhood is less than *number_of_objects_around*. If they have picked a color, they drop it on a black cell if they have encountered at least
* *number_of_objects_in_history* cells with the same color.\n After a while, colors begin to be aggregated.
* Tags: gui, skill, grid
* Some modifications have been made for demonstrative purposes
*/
model ant_sort
global {
// Parameters
int number_of_different_colors <- 6 max: 9 ;
int density_percent <- 30 min: 0 max: 99 ;
int number_of_objects_in_history <- 3 min: 0 ;
int number_of_objects_around <- 5 min: 0 max: 8;
int width_and_height_of_grid <- 128 max: 400 min: 10 ;
int ants <- 20 min: 1 ;
int new_variable <- 0;
list<rgb> colors <- [#yellow,#red, #orange, #blue, #green,#cyan, #gray,#pink,#magenta] ;
init {
create ant number: ants;
}
}
//Species ant that will move and follow a final state machine
species ant skills: [moving] control: fsm {
rgb color <- #white ;
ant_grid place -> ant_grid (location) ;
//Reflex to make the ant wander
reflex wandering {
do wander amplitude: 120.0;
}
//Initial state that will change to full
state empty initial: true {
transition to: full when: (place.color != #black) and ((place.neighbors count (each.color = place.color)) < (rnd(number_of_objects_around))) {
color <- place.color ;
place.color <- #black ;
}
}
//State full that will change to black if the place color is empty and drop the color inside it
History
Ant Sorting.gaml
Revision Time
9/5/21, 1:40 pm
26/2/21, 1:51 pm
Open
Open With
Compare Current with Local
Get Contents
98M of 824M



GAMA WORKSPACE - Compare /Toy Models/Ants (Foraging and Sorting)/models/Ant Sorting.gaml Current and Local Revision - Gama
File Edit Search Views Help
No simulation running
GAML reference (Ctrl+Shift+H)
Models
Ant Sorting.gaml
Find model...
Library models (7 projects)
Data (60 models)
GAML Syntax (35 models)
Model Exploration (3 models)
Modeling (46 models)
Toy Models (83 models)
Ants (Foraging and Sorting) (2 models)
images
models (2 models)
Ant Foraging.gaml (4 experiments)
Ant Sorting.gaml (1 experiment)
Tags
Contents
Experiment Color sort
Art (6 models)
Boids (4 models)
Bubble Sort (1 model)
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
welcome.html
Ant Sorting.gaml
Compare Ant Sorting.gaml Current and Local Revision
Text Compare
Local: Ant Sorting.gaml
Local history: Ant Sorting.gaml 26 Feb 2021, 1:51:43 pm
/**
* Name: Ant Sorting
* Author:
* Description: This model is loosely based on the behavior of ants sorting different elements in
* The grid itself contains cells of different colors. Each step, the agents move randomly. If
* neighbourhood is less than *number_of_objects_around*. If they have picked a color, they drop
* *number_of_objects_in_history* cells with the same color.\n After a while, colors begin to b
* Tags: gui, skill, grid
* Some modifications have been made for demonstrative purposes
*/
model ant_sort
global {
// Parameters
int number_of_different_colors <- 6 max: 9 ;
int density_percent <- 30 min: 0 max: 99 ;
int number_of_objects_in_history <- 3 min: 0 ;
int number_of_objects_around <- 5 min: 0 max: 8;
int width_and_height_of_grid <- 128 max: 400 min: 10 ;
int ants <- 20 min: 1 ;
int new_variable <- 0;
list<rgb> colors <- [#yellow,#red, #orange, #blue, #green,#cyan, #gray,#pink,#magenta] ;
init {
create ant number: ants;
}
}
//Species ant that will move and follow a final state machine
species ant skills: [moving] control: fsm {
rgb color <- #white ;
ant_grid place -> ant_grid (location) ;
//Reflex to make the ant wander
reflex wandering {
do wander amplitude: 120.0;
}
//Initial state that will change to full
state empty initial: true {
transition to: full when: (place.color != #black) and ((place.neighbors count (each.col
color <- place.color ;
place.color <- #black ;
}
}
int number_of_different_colors <- 5 max: 9 ;
//State full that will change to black if the place color is empty and drop the color in
state full {
Validation
1311 items
Description
Project
Resource
Information (1310 items)
Tasks (1 item)
History
Ant Sorting.gaml
Revision Time
9/5/21, 1:40 pm
26/2/21, 1:51 pm
Left: 10 : 1, Right: 9 : 1, incoming deletion #1 (Left: 9 : 9, Right: before line 9)
111M of 824M

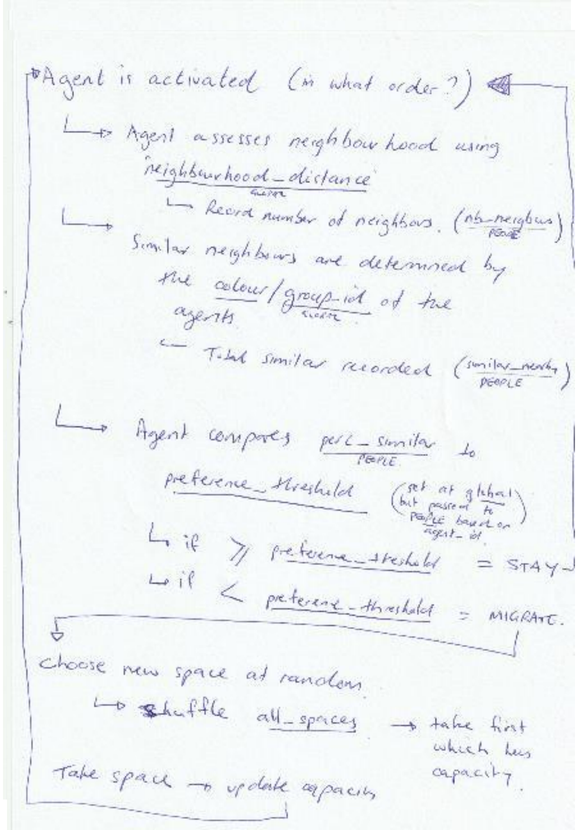
Model design – Process Diagrams

Code Less, Think More

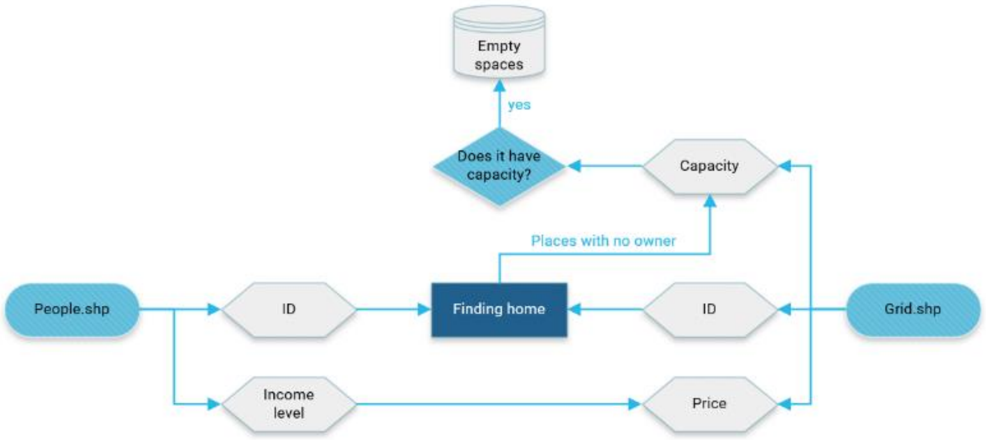
What variables are needed?

What steps are required?

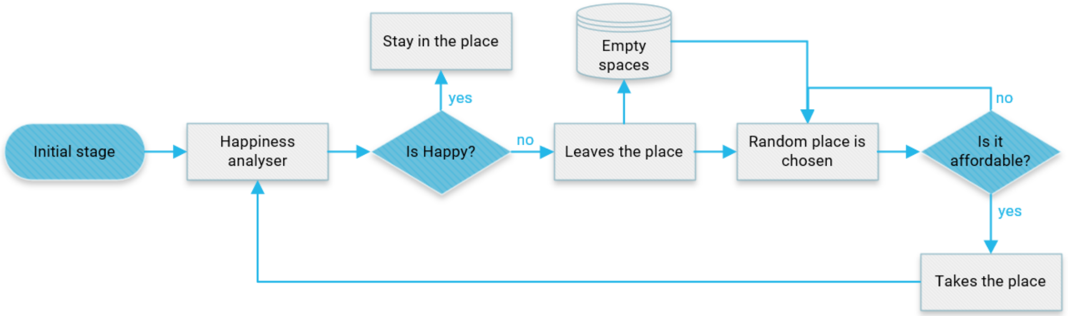
In what order?



INITIALISATION



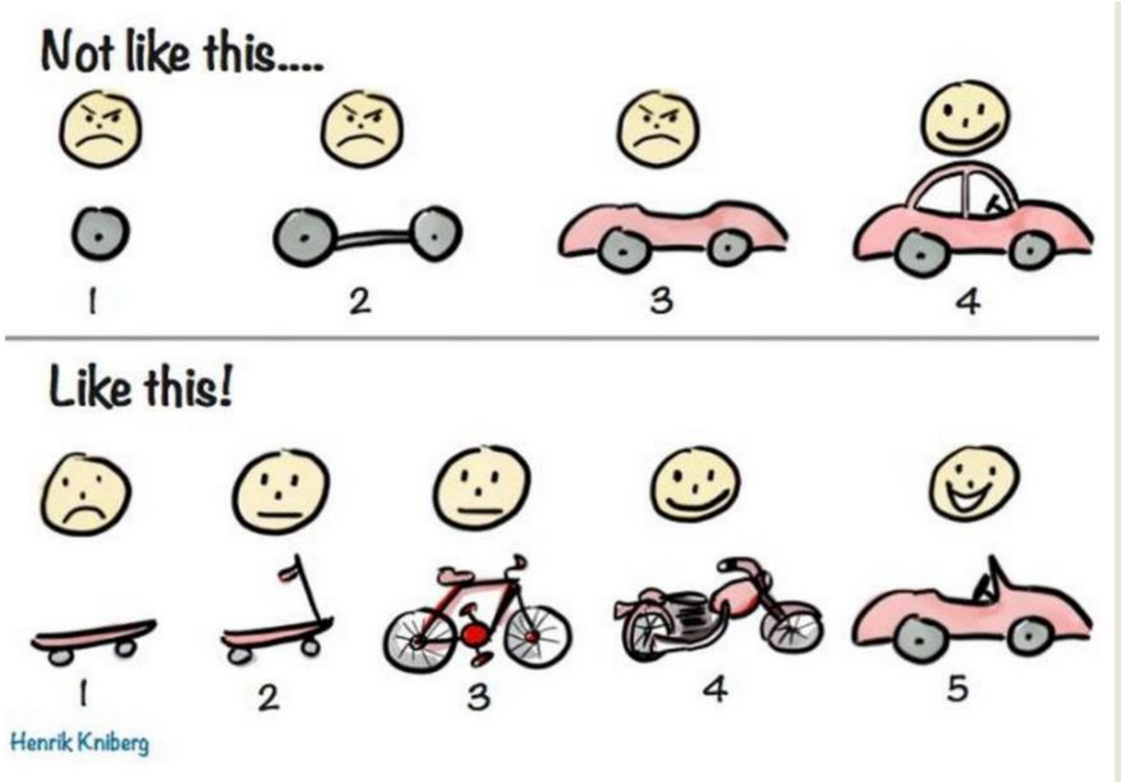
ITERATIONS / CYCLES



+ OUTPUTS – WHEN – WHAT VARIABLES – WHAT FORMAT

Model validation

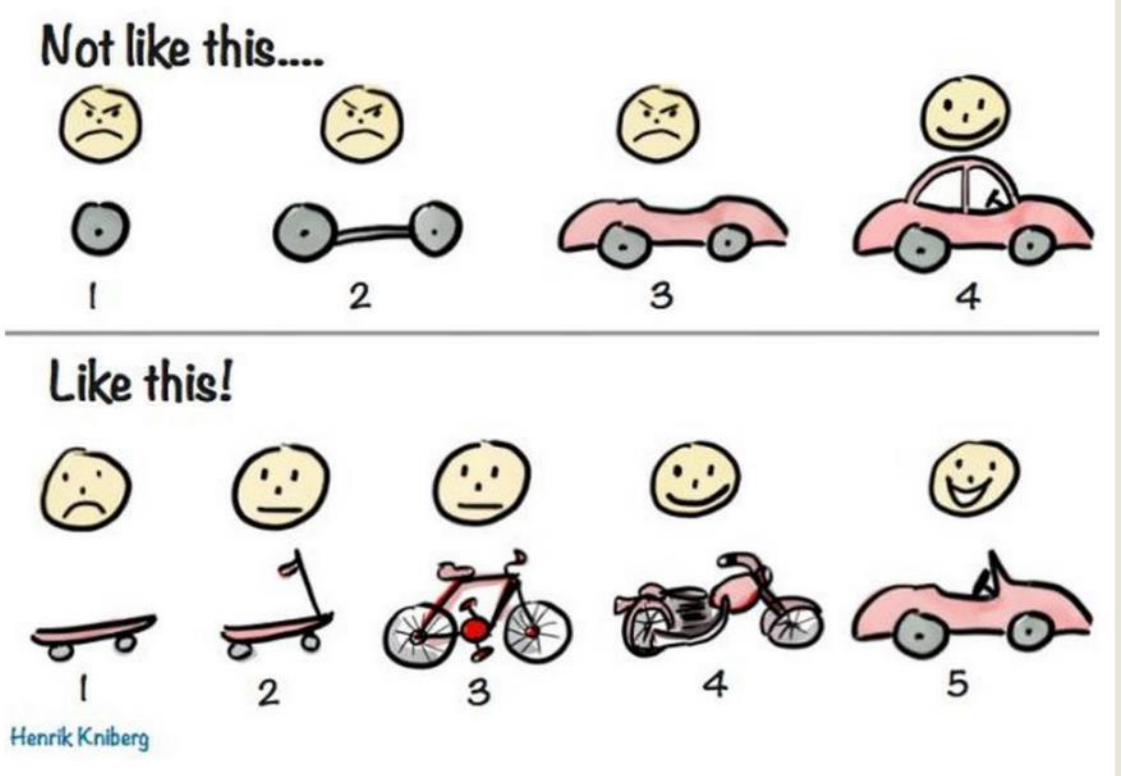
- Incremental change



https://levelup.gitconnected.com/code-less-think-more-incrementally-98adee22df9b

Model validation

- Incremental change
- Export and compare
- ‘write’ statement



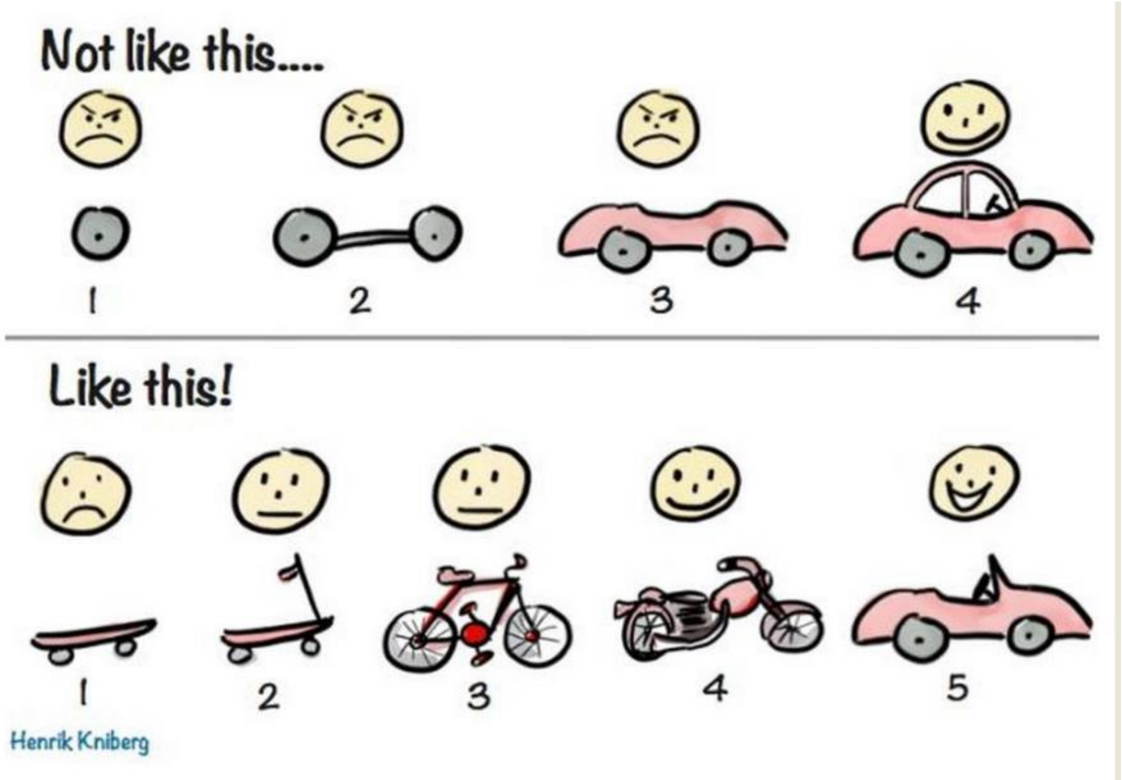
https://levelup.gitconnected.com/code-less-think-more-incrementally-98adee22df9b

```
//Initialization of the model
init {
do initialize_places;
do initialize_people;
//Write the number of agents created
write string(length(people as list)) + " people agents created";
ask space {do update_happy;}

/*
//save initial position  - only need to run once to get the reports
save space type: "shp" to: "C:/Users/PAGEMA1/Documents/GAMA/FINAL DATA/results/" + sort_variable + "_init" + ".shp" attributes:
["cell_id","capacity","insiders", "grid_id","group1_within","group2_within","group3_within","G1happy","G2happy","G3happy"] crs: "EPSG:3067";
do pause;
*/

}
```

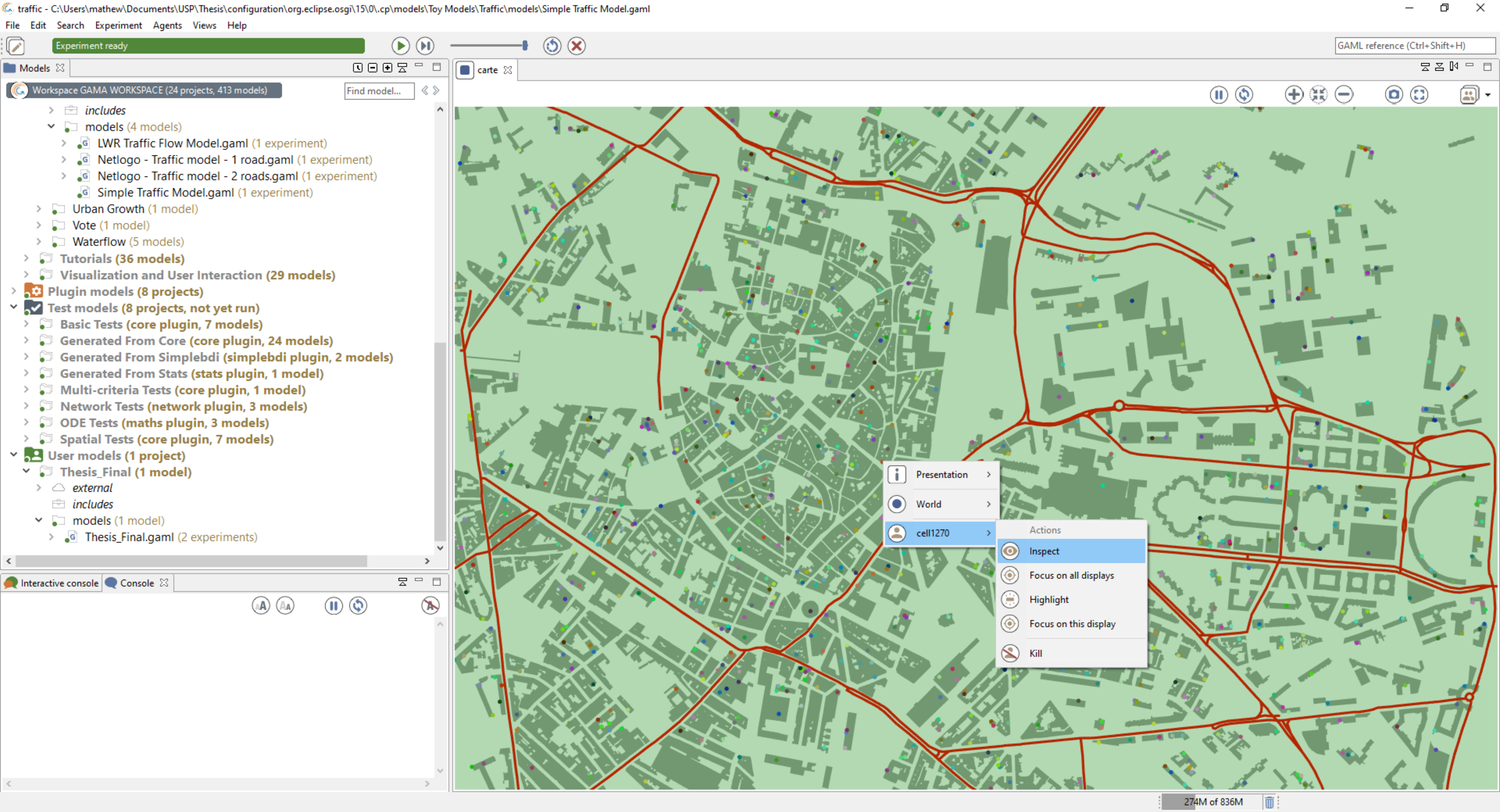
Model validation

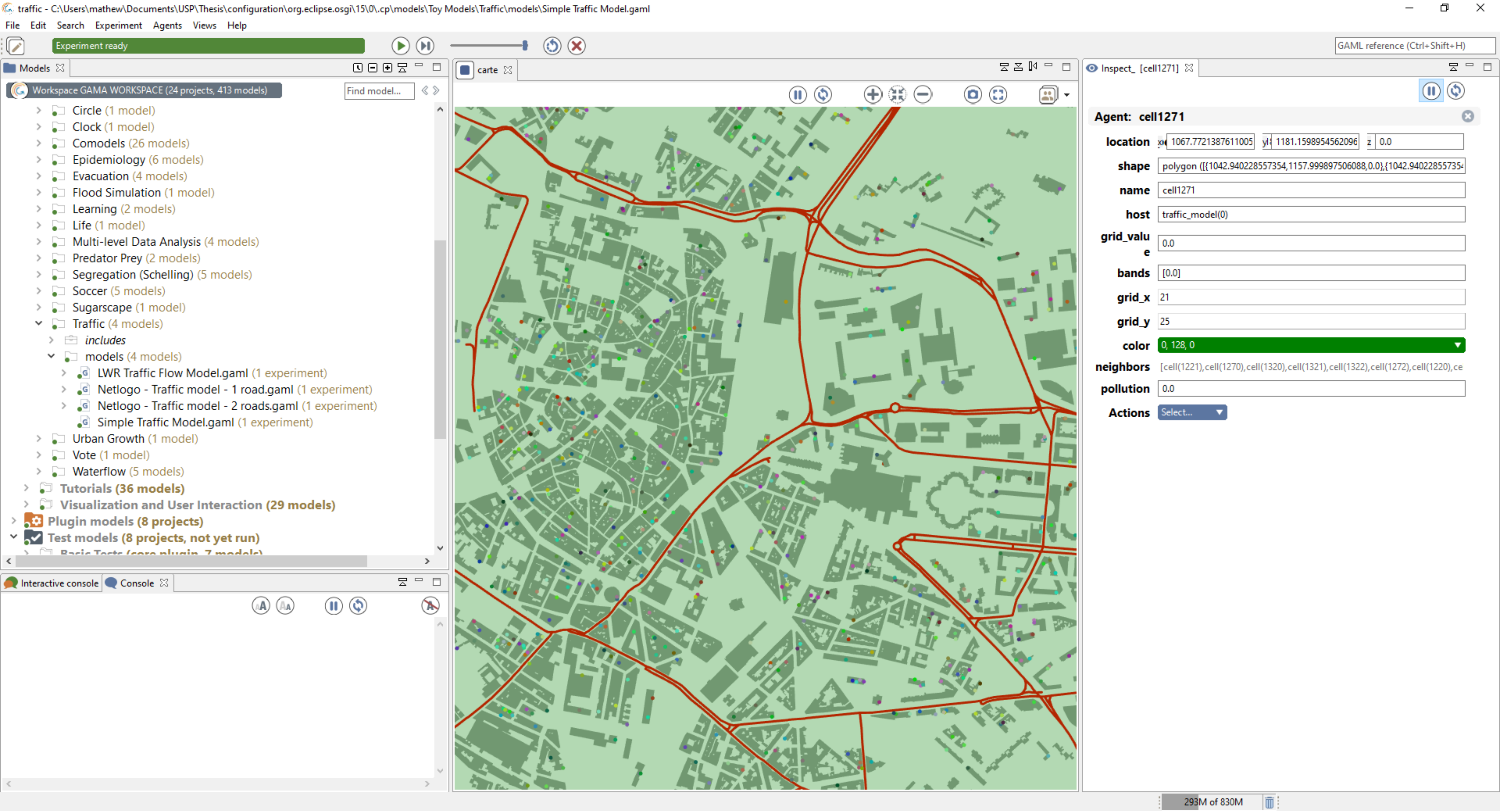
- Incremental change
- Export and compare
- ‘write’ statement
- Inspect agents in the experiment to make sure the are acting as expected

Video on how to use the interactive console:
https://www.youtube.com/watch?v=GAPFCKCT1q8



https://levelup.gitconnected.com/code-less-think-more-incrementally-98adee22df9b


traffic - C:\Users\mathew\Documents\USP\Thesis\configuration\org.eclipse.osgi\15\0\.cp\models\Toy Models\Traffic\models\Simple Traffic Model.gaml
File
Edit
Search
Experiment
Agents
Views
Help
Experiment ready
GAML reference (Ctrl+Shift+H)
Models
Workspace GAMA WORKSPACE (24 projects, 413 models)
Find model...
includes
models (4 models)
LWR Traffic Flow Model.gaml (1 experiment)
Netlogo - Traffic model - 1 road.gaml (1 experiment)
Netlogo - Traffic model - 2 roads.gaml (1 experiment)
Simple Traffic Model.gaml (1 experiment)
Urban Growth (1 model)
Vote (1 model)
Waterflow (5 models)
Tutorials (36 models)
Visualization and User Interaction (29 models)
Plugin models (8 projects)
Test models (8 projects, not yet run)
Basic Tests (core plugin, 7 models)
Generated From Core (core plugin, 24 models)
Generated From Simplebdi (simplebdi plugin, 2 models)
Generated From Stats (stats plugin, 1 model)
Multi-criteria Tests (core plugin, 1 model)
Network Tests (network plugin, 3 models)
ODE Tests (maths plugin, 3 models)
Spatial Tests (core plugin, 7 models)
User models (1 project)
Thesis_Final (1 model)
external
includes
models (1 model)
Thesis_Final.gaml (2 experiments)
Interactive console
Console
carte
Presentation
World
cell1270
Actions
Inspect
Focus on all displays
Highlight
Focus on this display
Kill
274M of 836M


traffic - C:\Users\mathew\Documents\USP\Thesis\configuration\org.eclipse.osgi\15\0\.cp\models\Toy Models\Traffic\models\Simple Traffic Model.gaml
File Edit Search Experiment Agents Views Help
Experiment ready
GAML reference (Ctrl+Shift+H)
Models
Workspace GAMA WORKSPACE (24 projects, 413 models)
Find model...
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
Segregation (Schelling) (5 models)
Soccer (5 models)
Sugarscape (1 model)
Traffic (4 models)
includes
models (4 models)
LWR Traffic Flow Model.gaml (1 experiment)
Netlogo - Traffic model - 1 road.gaml (1 experiment)
Netlogo - Traffic model - 2 roads.gaml (1 experiment)
Simple Traffic Model.gaml (1 experiment)
Urban Growth (1 model)
Vote (1 model)
Waterflow (5 models)
Tutorials (36 models)
Visualization and User Interaction (29 models)
Plugin models (8 projects)
Test models (8 projects, not yet run)
Interactive console
Console
carte
Inspect_ [cell1271]
Agent: cell1271
location 1067.7721387611005 1181.1598954562096 z 0.0
shape polygon ([{1042.940228557354,1157.999897506088,0.0},{1042.94022855735
name cell1271
host traffic_model(0)
grid_value 0.0
bands [0.0]
grid_x 21
grid_y 25
color 0, 128, 0
neighbors [cell(1221),cell(1270),cell(1320),cell(1321),cell(1322),cell(1272),cell(1220),ce
pollution 0.0
Actions Select...
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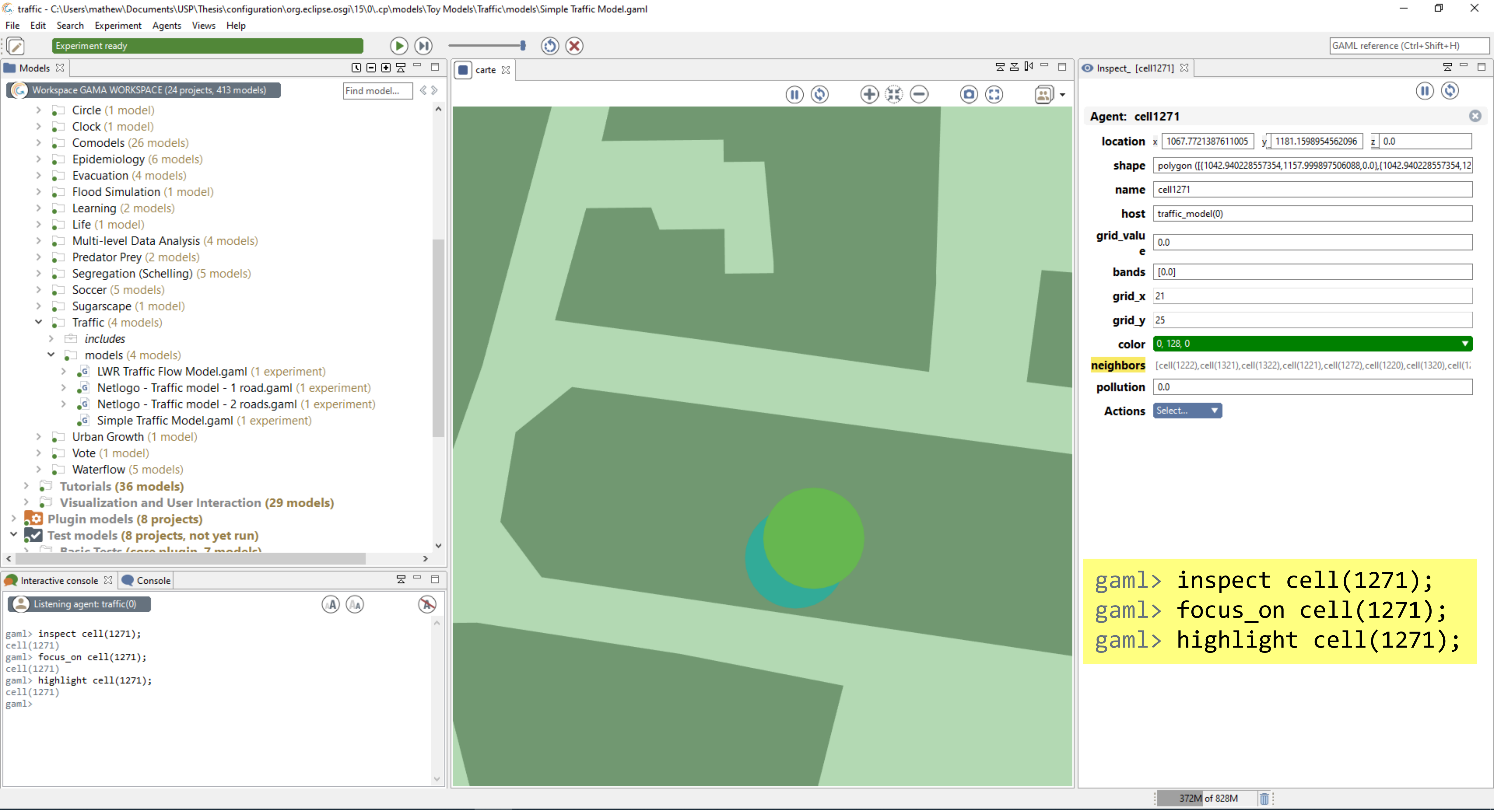
traffic - C:\Users\mathew\Documents\USP\Thesis\configuration\org.eclipse.osgi\15\0\.cp\models\Toy Models\Traffic\models\Simple Traffic Model.gaml
File Edit Search Experiment Agents Views Help
Experiment ready
GAML reference (Ctrl+Shift+H)
Models
Workspace GAMA WORKSPACE (24 projects, 413 models)
Find model...
Circle (1 model)
Clock (1 model)
Comodels (26 models)
Epidemiology (6 models)
Evacuation (4 models)
Flood Simulation (1 model)
Learning (2 models)
Life (1 model)
Multi-level Data Analysis (4 models)
Predator Prey (2 models)
Segregation (Schelling) (5 models)
Soccer (5 models)
Sugarscape (1 model)
Traffic (4 models)
includes
models (4 models)
LWR Traffic Flow Model.gaml (1 experiment)
Netlogo - Traffic model - 1 road.gaml (1 experiment)
Netlogo - Traffic model - 2 roads.gaml (1 experiment)
Simple Traffic Model.gaml (1 experiment)
Urban Growth (1 model)
Vote (1 model)
Waterflow (5 models)
Tutorials (36 models)
Visualization and User Interaction (29 models)
Plugin models (8 projects)
Test models (8 projects, not yet run)
carte
Inspect_ [cell1271]
Agent: cell1271
location x 1067.7721387611005 y 1181.1598954562096 z 0.0
shape polygon ([{1042.940228557354,1157.999897506088,0.0},{1042.940228557354,12
name cell1271
host traffic_model(0)
grid_value 0.0
bands [0.0]
grid_x 21
grid_y 25
color 0, 128, 0
neighbors [cell(1222),cell(1321),cell(1322),cell(1221),cell(1272),cell(1220),cell(1320),cell(1
pollution 0.0
Actions Select...
gaml> inspect cell(1271);
gaml> focus_on cell(1271);
gaml> highlight cell(1271);
Interactive console
Console
Listening agent: traffic(0)
gaml> inspect cell(1271);
cell(1271)
gaml> focus_on cell(1271);
cell(1271)
gaml> highlight cell(1271);
cell(1271)
gaml>
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Big Data Sets

- Create a subset of the data to use during the early stages of design
- Quicker + Easier to manually verify

Defining Export Files

It is possible to directly use global variables in the model - but if you want to export data - you have to have it stored at the species level

https://gama-platform.github.io/wiki/DefiningExportFiles

Basic syntax:

```
save data to: output_file type: a_type_file;
```

To save data in a text file:

```
save (string(cycle) + "->" + name + ":" + location) to: "save_data.txt" type: "text";
```

To save the values of some attributes of the current agent in csv file:

```
save [name, location, host] to: "save_data.csv" type: "csv";
```

To save the geometries of all the agents of a species into a shapefile (with optional attributes):

```
save species_of(self) to: "save_shapefile.shp" type: "shp" attributes: [name::"nameAgent", location::"locationAgent"] crs: "EPSG:4326";
```

Batch Processing

gui : experiment with a graphical interface, which displays its input parameters and outputs.
batch : Allows to setup a series of simulations simultaneously (without graphical interface).

```
experiment batch_experiment type: batch repeat: 10 until: (cycle = 21)  {

reflex end_of_runs {

    int cpt <- 1;

    ask simulations {

        save people type: "shp" to: "C:/Users/mathew/Documents/agent_shapefile_" + cpt + ".shp" attributes: ["agent_id","group_id",
            "current_building","percent_similar_wanted","total_nearby","similar_nearby"] crs: "EPSG:3067";

        save space type: "shp" to: "C:/Users/mathew/Documents/space_shapefile_" + cpt + ".shp" attributes: ["cell_id","capacity","insiders",
            "grid_id","group1_within","group2_within","group3_within","G1happy","G2happy","G3happy"] crs: "EPSG:3067";

        cpt <- cpt + 1;
```

Questions?