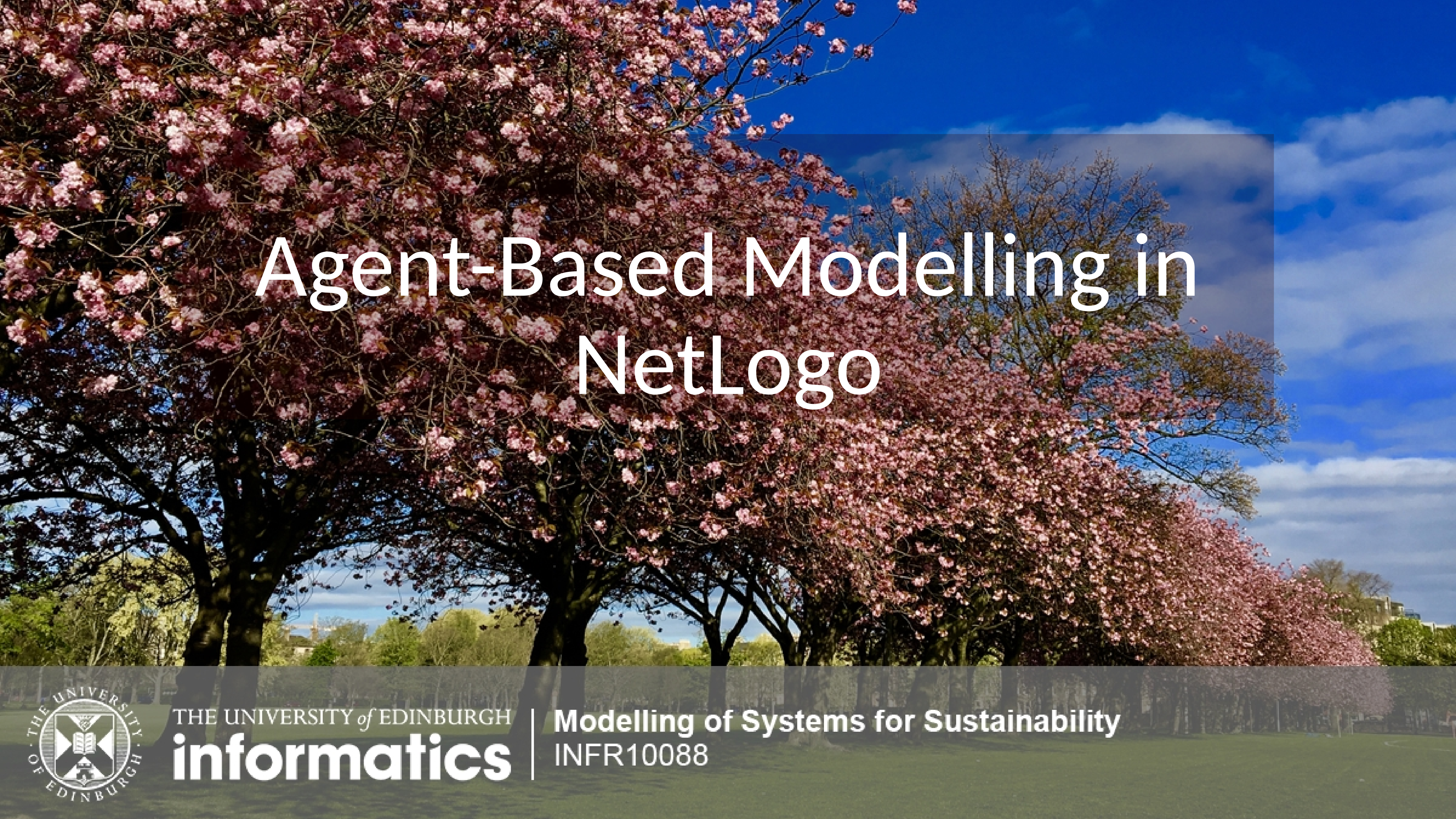


Agent-Based Modelling in NetLogo

THE UNIVERSITY *of* EDINBURGH

informatics

Modelling of Systems for Sustainability

INFR10088

Previously

- Modelling cycle, brief intro ABM/SD
- Formulating a model in the ODD protocol
- Today: Agent-Based Modelling in NetLogo

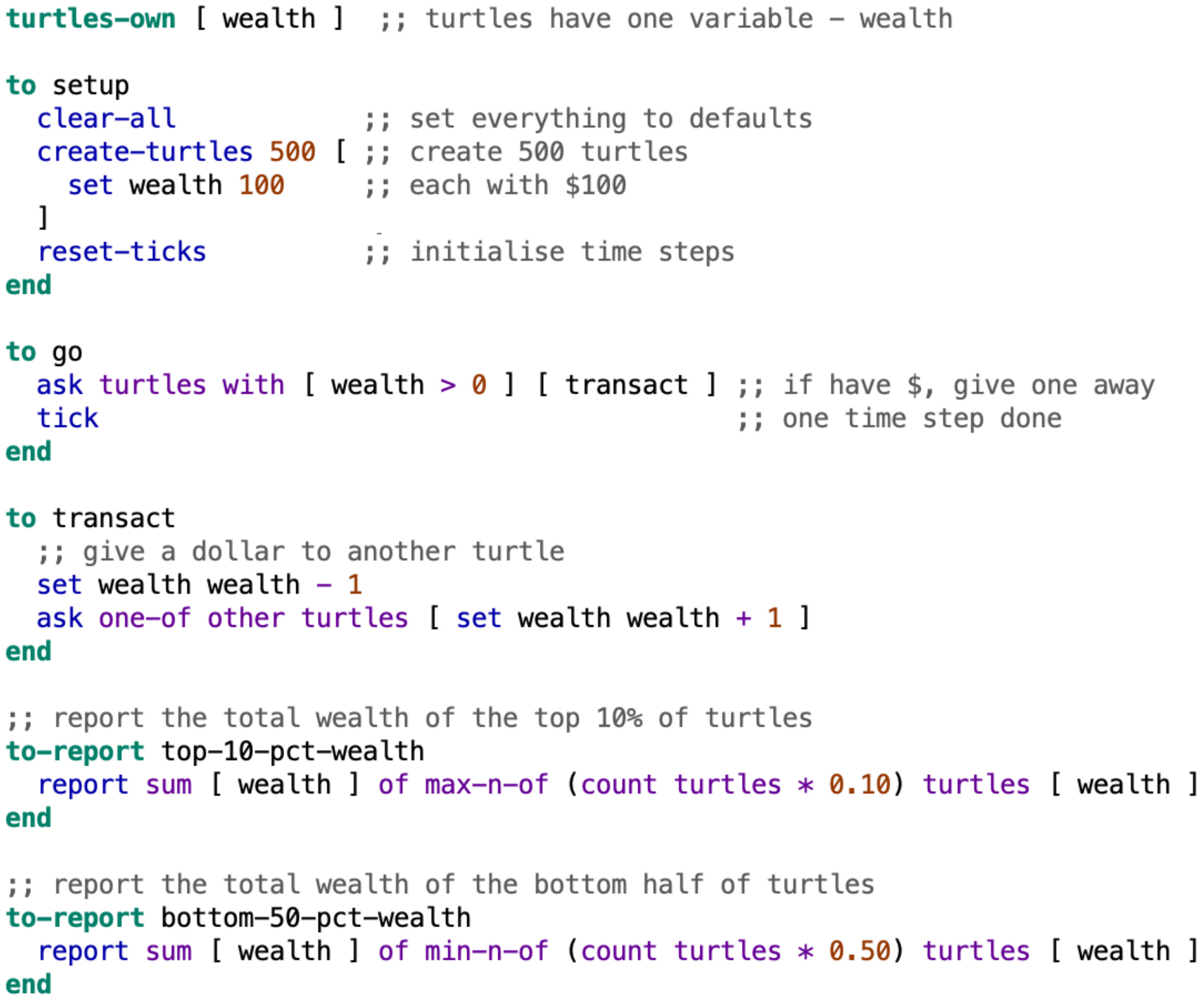
ABM key aspects

- Agent types and numbers
- Communication
- Shared environment
- Spatial/Network component?
- Scheduling/ordering

Simple Economy example

- Scenario: initially everyone has the same wealth. At each time step, each person gives $1 to someone else chosen at random, if they have money to give.
- Question: what happens to the wealth distribution over time?
- Initialisation: set up 500 agents each with $100
- Agent behaviour: as in scenario above
- Observation
  - The distribution of wealth across the population
  - The total wealth of the top 10% and of the bottom 50%

Simple Economy: code



```
turtles-own [ wealth ]  ;; turtles have one variable - wealth

to setup
  clear-all            ;; set everything to defaults
  create-turtles 500 [ ;; create 500 turtles
    set wealth 100     ;; each with $100
  ]
  reset-ticks          ;; initialise time steps
end

to go
  ask turtles with [ wealth > 0 ] [ transact ] ;; if have $, give one away
  tick                                         ;; one time step done
end

to transact
  ;; give a dollar to another turtle
  set wealth wealth - 1
  ask one-of other turtles [ set wealth wealth + 1 ]
end

;; report the total wealth of the top 10% of turtles
to-report top-10-pct-wealth
  report sum [ wealth ] of max-n-of (count turtles * 0.10) turtles [ wealth ]
end

;; report the total wealth of the bottom half of turtles
to-report bottom-50-pct-wealth
  report sum [ wealth ] of min-n-of (count turtles * 0.50) turtles [ wealth ]
end
```

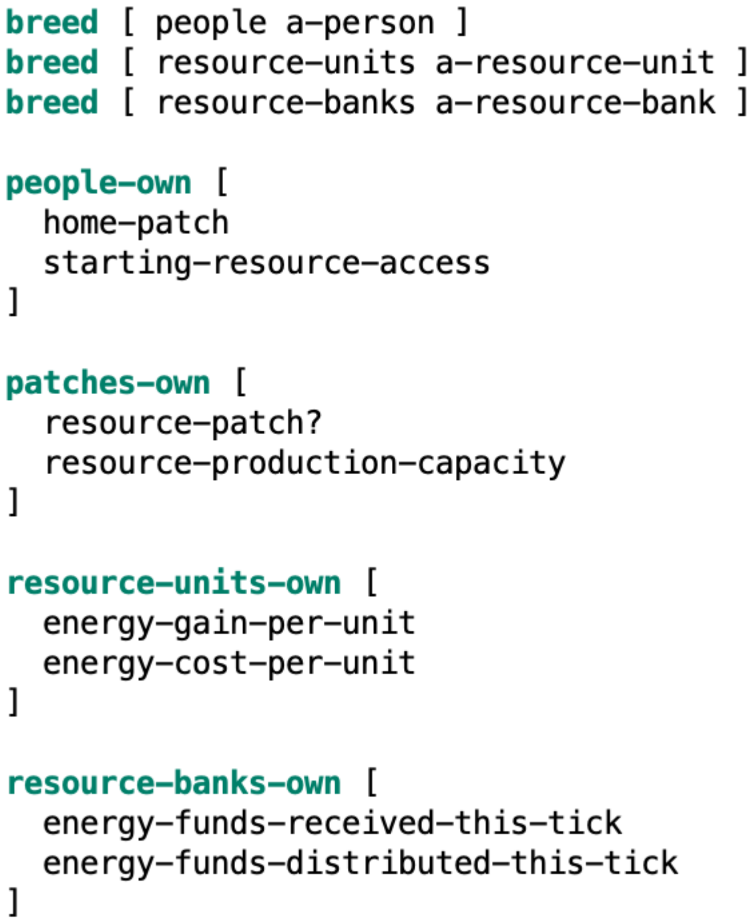
Simple Economy: run

Agent types

- Turtle – what you think of as an agent
  - Has x, y coordinates
- Link – link between two Turtles
  - Can be directed or undirected
- Patch – spatial area
  - Has x, y coordinates
- The observer
  - That’s you, using the GUI
  - BehaviourSpace to automate

Turtles

- A class of turtle is called a breed
- Declared at the beginning of the code
- Different breeds have different variables
  - Breed not fixed!
- Set of turtles is an agentset
- Can ‘hatch’ new turtles
  - Same breed
  - Same variable values

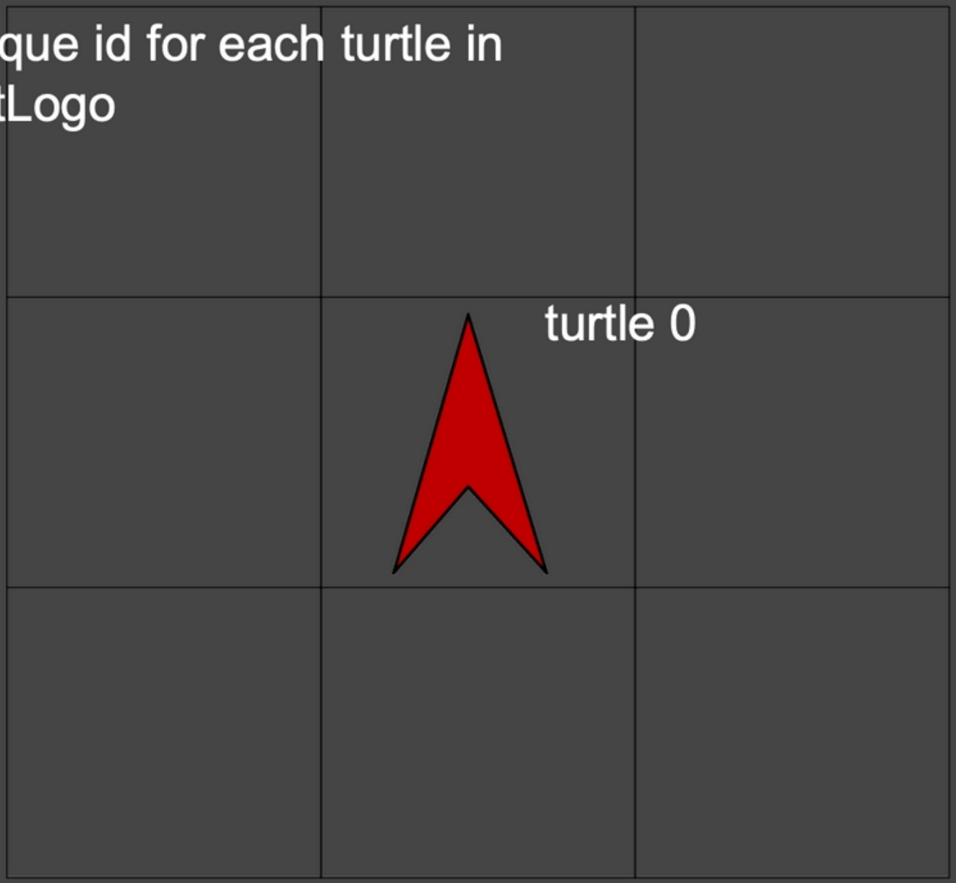


```
breed [ people a-person ]
breed [ resource-units a-resource-unit ]
breed [ resource-banks a-resource-bank ]

people-own [
  home-patch
  starting-resource-access
]

patches-own [
  resource-patch?
  resource-production-capacity
]

resource-units-own [
  energy-gain-per-unit
  energy-cost-per-unit
]

resource-banks-own [
  energy-funds-received-this-tick
  energy-funds-distributed-this-tick
]
```

Properties

- who
- heading
- xcor
- ycor
- shape
- size
- color
- hidden?

- unique id for each turtle in NetLogo



Gabriel Wurzer: „An Introduction to NetLogo“, in Agents in Archeology Workshop 2011, Netlogo Lecture, Slide 19, Vienna.

Links

- Used to pass/process information between turtles
- Undirectional – only one between any two turtles
- Directional – can be one in each direction between any two turtles
- No self-links
- Good for modelling non-spatial networks
- Set of links is an agentset
- Can have breeds (types) of links
  - Modifies rules above
  - e.g. : undirected-link-breed [streets street]

Patches

- Notionally a 2D grid
  - Good for modelling many physical-world systems
- Cannot move – x and y coordinates are fixed
- Can ‘sprout’ new turtles
  - Any breed
- Agentset – ‘patches’
- Variables
  - pcolor, plabel, plabel-color, pxcor, pycor
- No breeds
  - Differentiate patches using patch variables

Observer

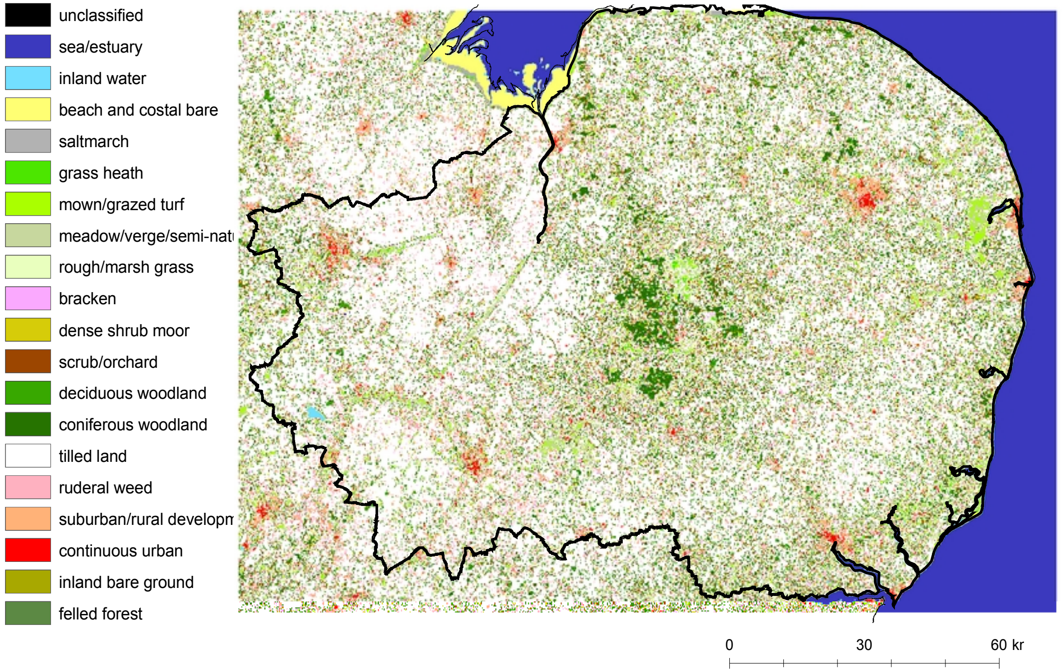
- Basically the GUI
- GUI connected to code
  - Input/Control: Button, Slider, Switch, Chooser
  - Output/View: Plot, Monitor, Model Settings
- Only agent able to arbitrarily ‘create’ turtles
  - But patches can ‘sprout’ and ‘hatch’

Observer – example

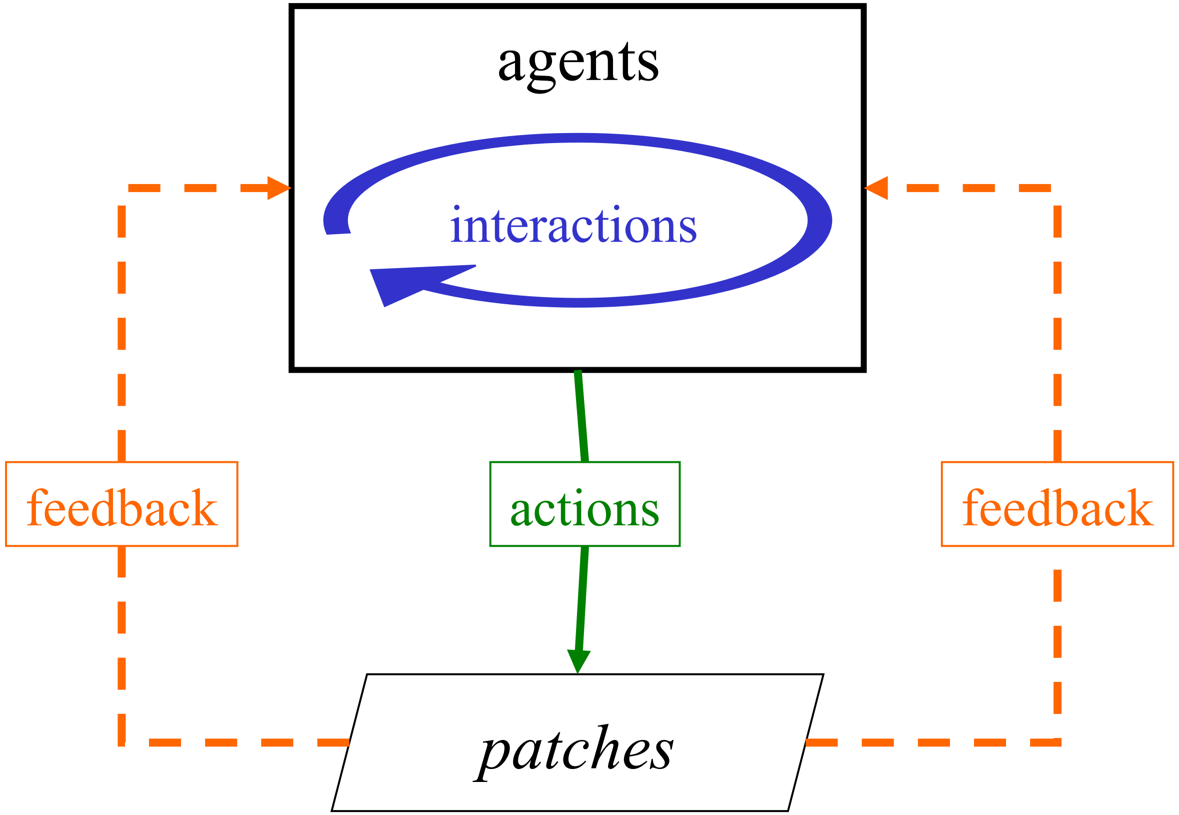
- Link to details on COMSES Model Library
- Link to ODD on Github
- Exploration of how collective action may or may not help with resource distribution in a climate change context
- Run in NetLogo

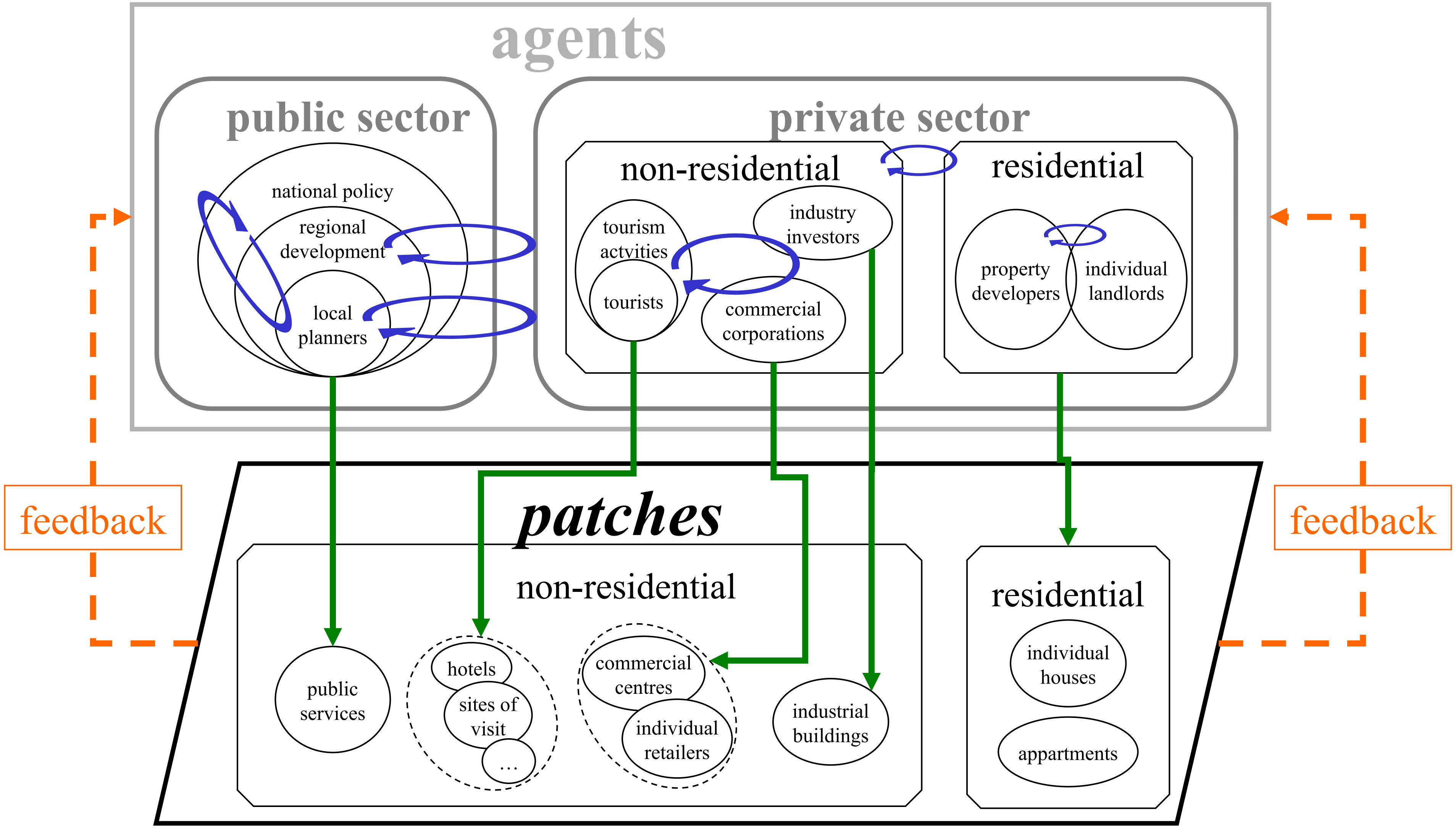
Example – urban land use in East Anglia

- Endogenising the planning process



Source: Lilibeth Acosta-Michlik and Corentin Fontaine; funded by the Tyndall Centre


agents
interactions
feedback
actions
feedback
patches

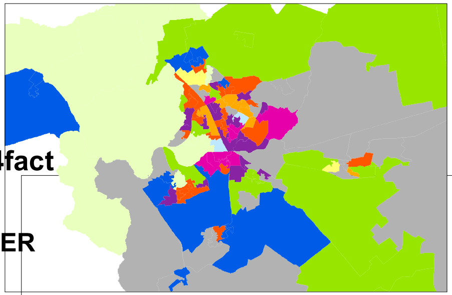

agents
public sector
national policy
regional development
local planners
private sector
non-residential
tourism actvities
tourists
industry investors
commercial corporations
residential
property developers
individual landlords
feedback
feedback
patches
non-residential
public services
hotels
sites of visit
…
commercial centres
individual retailers
industrial buildings
residential
individual houses
appartments

Residential agents

- Socio-economic data analysis
- Agent profiles (household types) & location trends

		CLUSTERS											
		1	2	3	4	5	6	7	8	9	10	11	12
isolated student	HA1										++	+	+++
single person	HA2							+	+++	++	++	+	
couple	HA3		++	+	+			+++	++		+++	++	
couple with dep. children	HA4			+		++		+++		+	+		
single-parent family	HA5					+++	++			++			+
couple with non-dep. children	HA6	+++	++	+	+								
all retired	HA7	+	+		+++		++						+

Household agent location preferences



Legend

LSOA_EA_clust12_4fact

■ <all other values>

clust_ward_12.CLUSTER

<Null>

■ 1 = HA6 - ... - HA7

■ 2 = ... - HA3/6 - HA7

■ 3 = ... - ... - HA3/4/6

■ 4 = HA7 - ... - HA3/6

■ 5 = HA5 - HA4 - ...

■ 6 = ... - HA5/7 - ...

■ 7 = HA3/4 HA2 - ...

■ 8 = HA2 - HA3 - ...

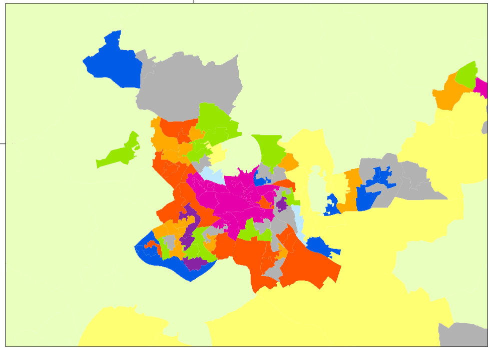
■ 9 = ... - HA2/5 - HA4

■ 10 = HA3 - HA1/2 - HA4

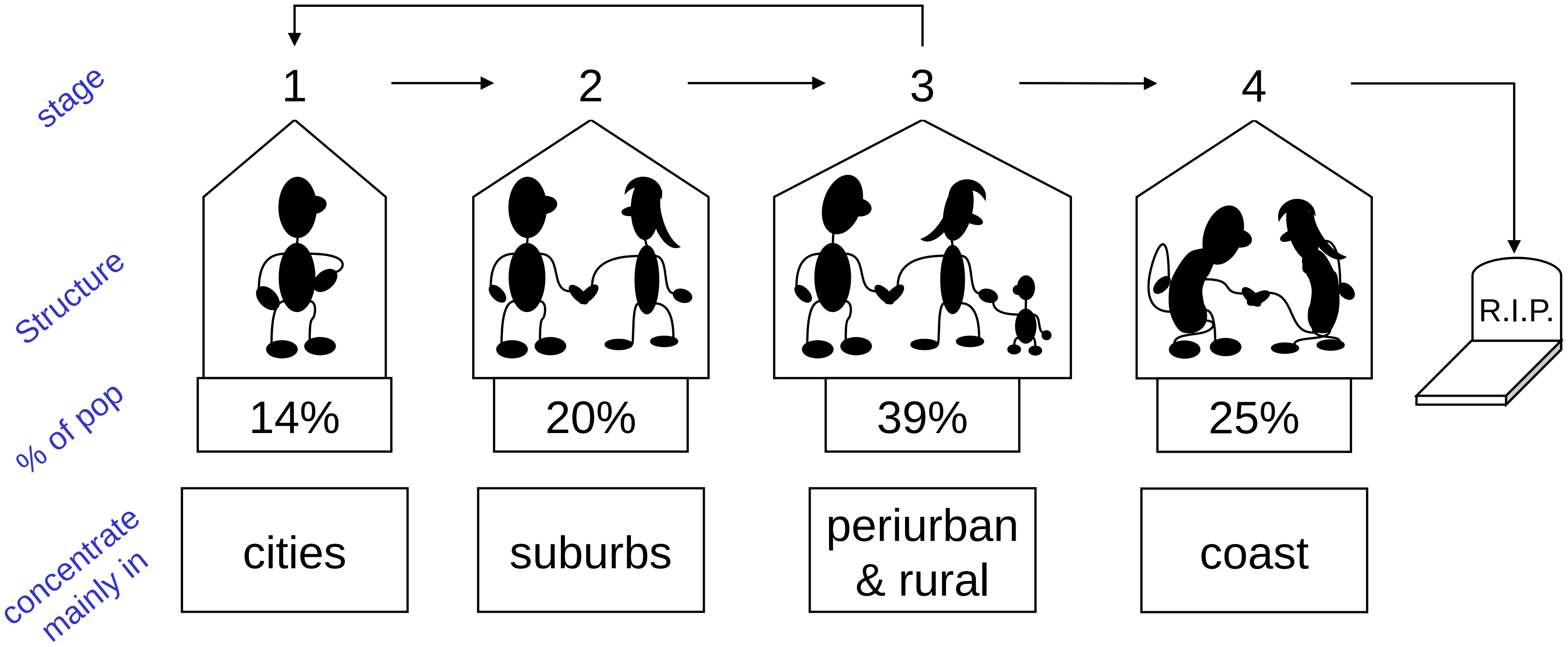
■ 11 = ... - HA3 - HA1/2

■ 12 = HA1 - ... - HA5/7

Demographics and coastal zone pressures



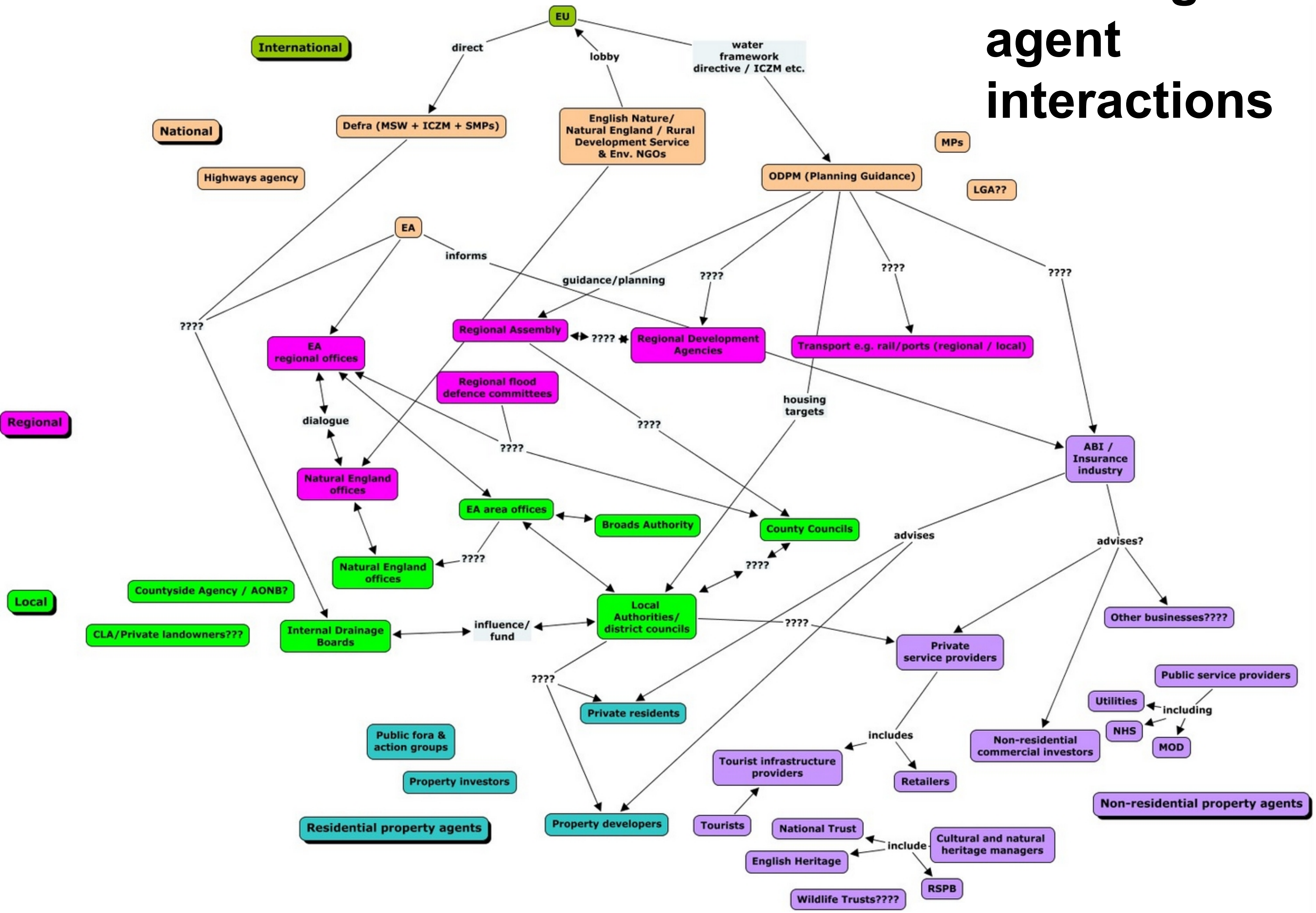
Residential model runs



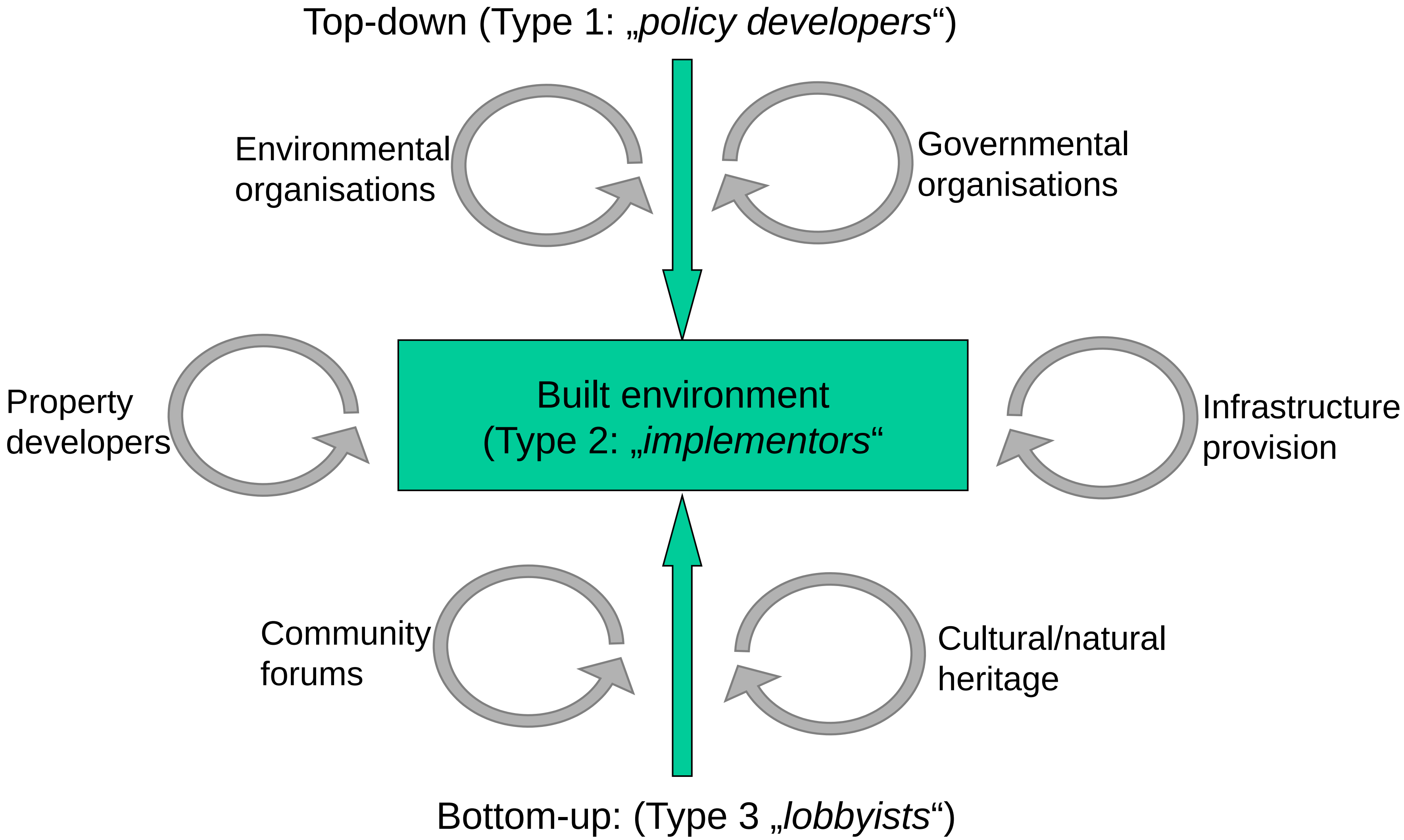
stage	1	2	3	4
Structure				
% of pop	14%	20%	39%	25%
concentrate mainly in	cities	suburbs	periurban & rural	coast

Model run animation

Planning agent interactions



Conceptual planning model



Top-down (Type 1: „*policy developers*“)

Environmental organisations

Governmental organisations

Property developers

Built environment (Type 2: „*implementors*“)

Infrastructure provision

Community forums

Cultural/natural heritage

Bottom-up: (Type 3 „*lobbyists*“)

ABM as Computational Laboratory

- Testing hypotheses
- Testing methodologies
- Is your ABM deterministic or has it got a stochastic component?
- How many simulations is enough?
- How do we interpret model results?
- Statistical analysis of results

Analysis of ABM Output

- Plot agent attributes
- Plot number of agents of certain type
- Spatial pattern metrics

    - temporal considerations (at a time or over time)