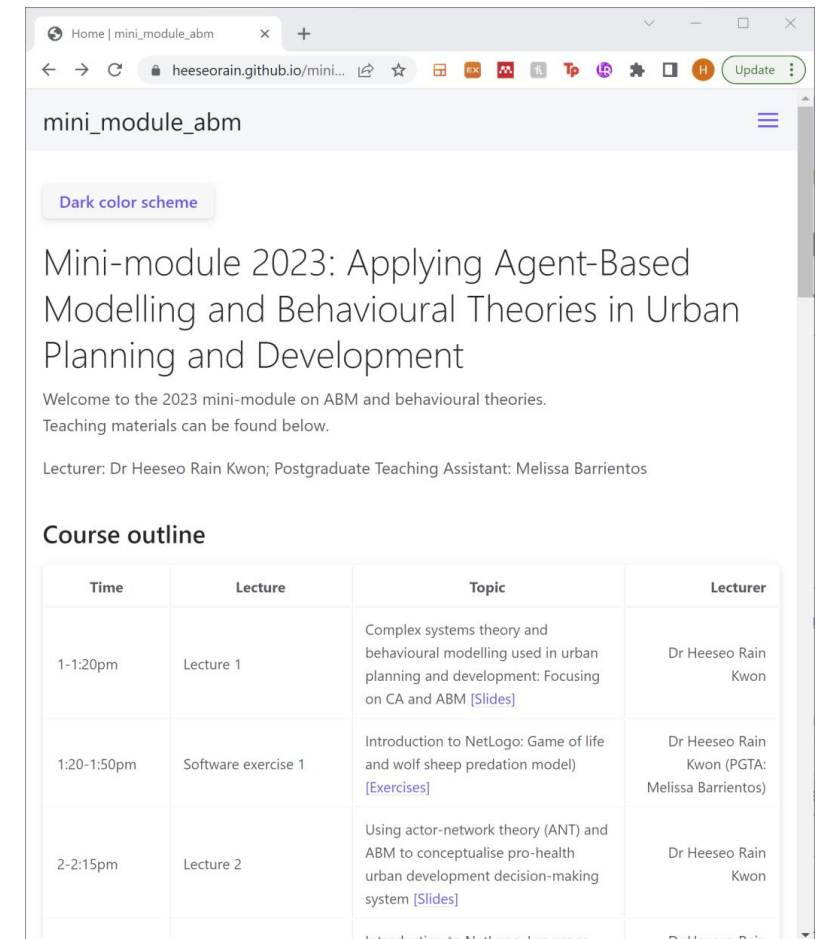# Welcome to the Mini-module 2023:
Applying Agent-Based Modelling and Behavioural Theories in Urban Planning and Development!

If you haven't done so already, please install NetLogo and QGIS:

- **NetLogo 6.2.1** (for Windows, choose 64-bit): https://ccl.northwestern.edu/netlogo/6.2.1/

- **QGIS 3.28 LTR** (Click the 'Looking for the more stable version? Get QGIS 3.28 LTR): https://www.qgis.org/en/site/forusers/download.html#

While we wait a little for people to arrive, you can have a look at the course material:

- https://heeseorain.github.io/mini_module_abm/

Welcome to the Mini-module 2023:
Applying Agent-Based Modelling and Behavioural Theories in Urban Planning and Development!
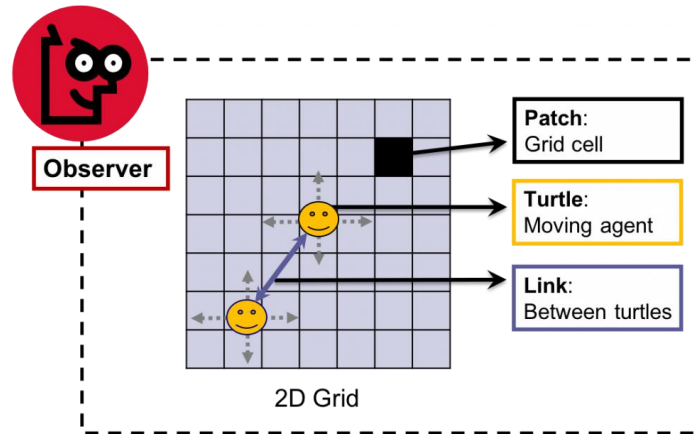
Dr Heeseo Rain Kwon

- **2010-2013**: BSc in Urban Planning, Design and Management, Bartlett School, UCL

- **2013-2016**: Researcher, Infrastructure Division, Korea Research Institute for Human Settlements (KRIHS)

- **2016-2017**: MPhil in Planning, Growth and Regeneration, Dep. of Land Economy, Univ. of Cambridge

- **2017-2020**: PhD in Land Economy, Dep. of Land Economy, Univ. of Cambridge

- **2020-2022**: Post-doc for Healthier Urban Development, Dep. of Real Estate and Planning, Univ. of Reading

- **2022-present**: BSP Post-doctoral Research Fellow, Bartlett School of Planning, UCL

Welcome to the Mini-module 2023:
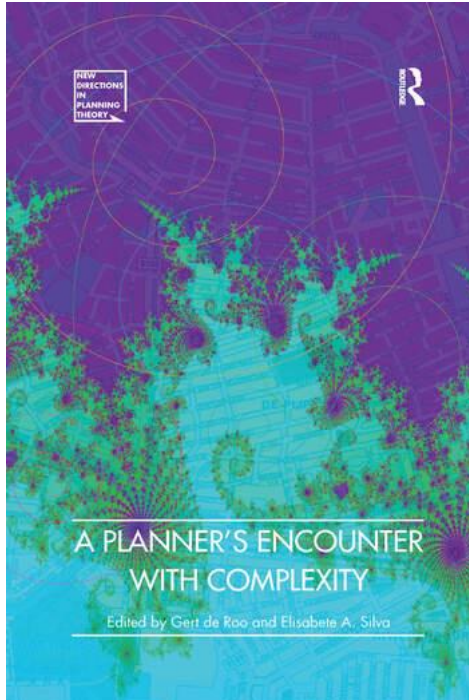## Applying Agent-Based Modelling and Behavioural Theories in Urban Planning and Development!

So that I get to know you, can you briefly share:

- Your name

- Which course are you in currently?

- What are your research interests?

- What do you want to learn the most today?

Lecture 1:

Complex systems theory and behavioural modelling used in urban planning and development: Focusing on CA and ABM

Dr Heeseo Rain Kwon

BSP Post-doctoral Research Fellow
Bartlett School of Planning, University College London
heeseo.kwon.10@ucl.ac.uk

Complexity theory (of complex systems theory)
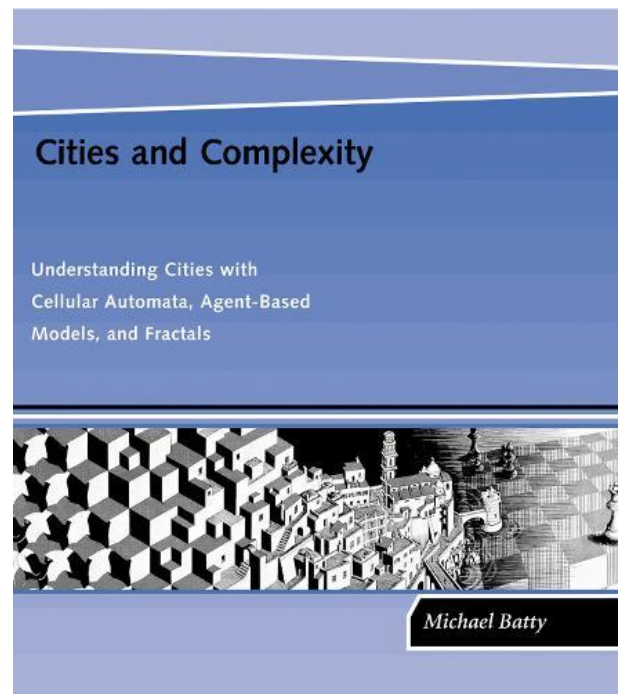
Any idea?

According to de Roo and Silva (2010), **complexity** "represents **dynamic realities** and **non-linear behavior**".

- The debate on "complex systems and their 'evolutionary' behaviour" has numerous origins such as "systems science, cybernetics, fractal geometry, fuzzy logic, **agent-based modelling, cellular automata**, meteorology, physics and biology" (p.2, 8)

"Cities are complex systems par excellence, more than the sum of their parts and developed through a multitude of individual and collective decisions from the bottom up to the top down."
(Batty et al., 2012: 483)

Cities and Complexity

Understanding Cities with
Cellular Automata, Agent-Based
Models, and Fractals

Michael Batty

THE EUROPEAN
PHYSICAL JOURNAL
SPECIAL TOPICS

Regular Article

Smart cities of the future

M. Batty[1,a], K.W. Axhausen[2], F. Giannotti[3], A. Pozdnoukhov[4], A. Bazzani[5], M. Wachowicz[6], G. Ouzounis[7], and Y. Portugali[8]

Applying complexity theory in urban planning to inform policies for positive behavioural change

- **Emergence**

- Patterns/phenomena that arise (often unexpectedly) from behaviour and interactions of individual agents

- **Non-linearity**

- Dynamics where output is difficult to be predicted from inputs

- **Feedback loops**

- Where behaviours reinforce one another e.g., virtuous or vicious cycle

- **Micro-interactions**

- e.g., human-human and human-environment interactions

Modelling of individual agent behaviours and their interactions in feedback loops with system-level behaviour
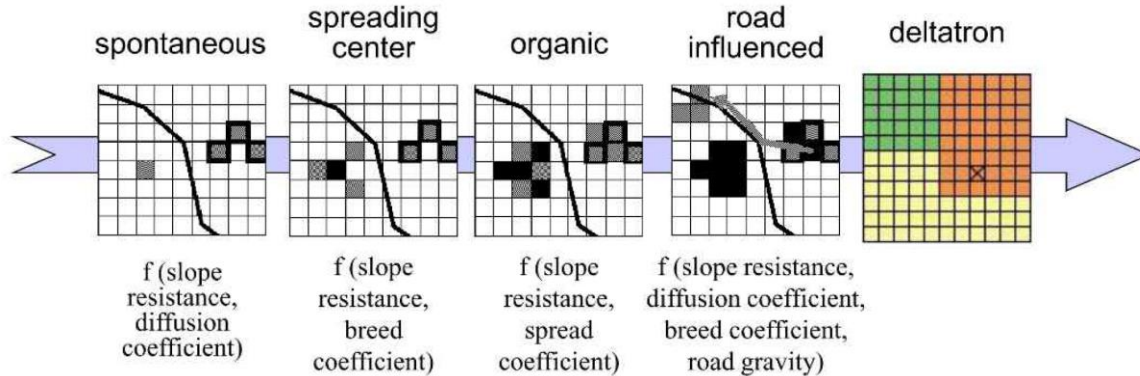

— Complex Adaptive System (CAS) —
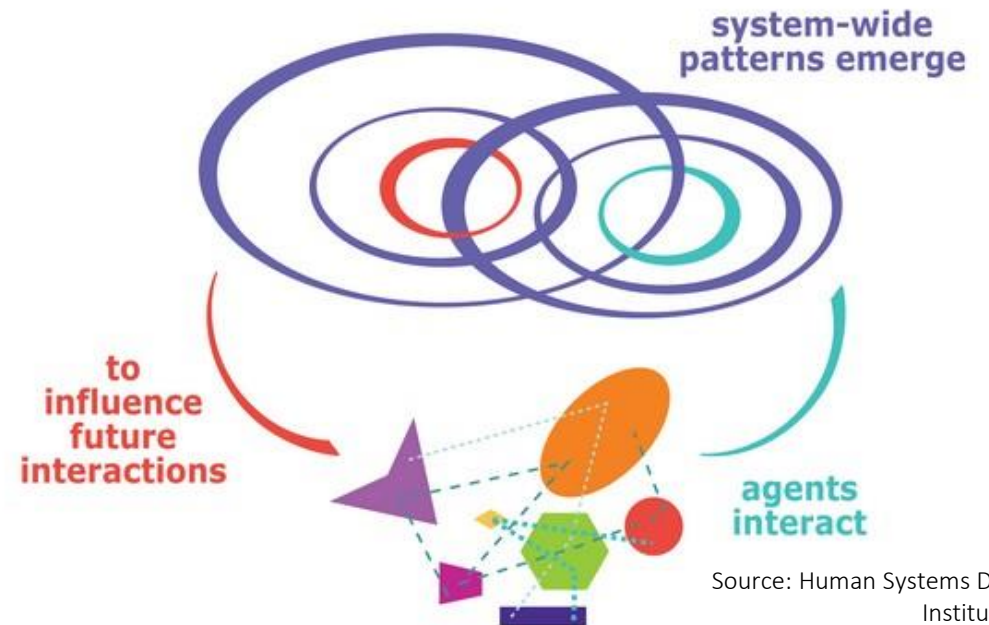
system-wide patterns emerge

to influence future interactions

agents interact

Source: Human Systems Dynamics Institute, 2016

Cellular Automata (CA) and Agent-Based Modelling (ABM): Different Strengths

Cellular Automata
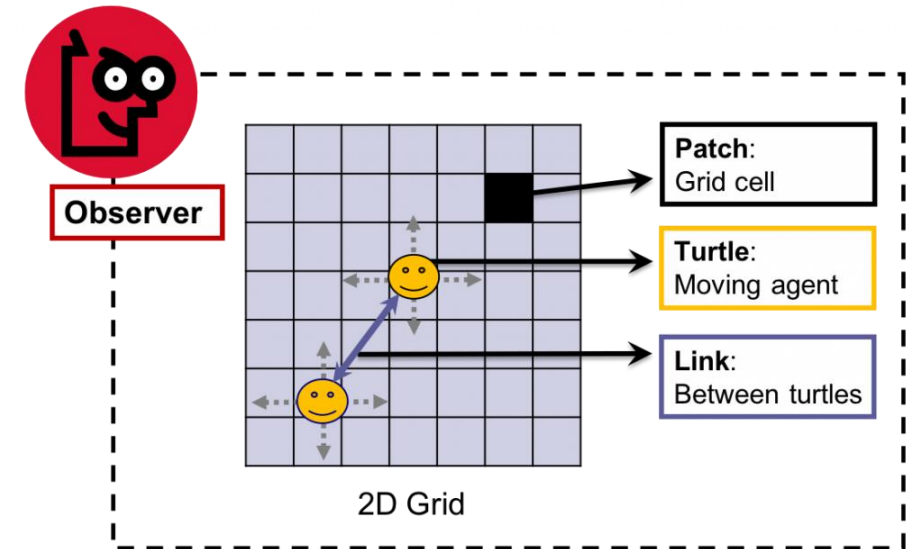### (e.g. SLEUTH urban growth model)

Particularly effective in modelling the spatial dynamics (e.g., land change)

Source: Clarke., 2019

Agent-Based Model
(e.g. on NetLogo platform)

Particular strength in simulating human decision-making dynamics and interaction with the environment

Source: Izquierdo et al., 2019

Cellular Automata (CA)

ScienceDirect

Cellular Automata

Cellular automata is "a collection of cells on a grid of specified shape that evolves over time according to a set of rules driven by the state of the neighboring cells [45], [70]," [69].
From: Building and Environment, 2017

Related terms:

Geomorphological Response, Land Use Change, Urban Growth, Land Cover Change, Tungsten, Markov Chain, Geographic Information System

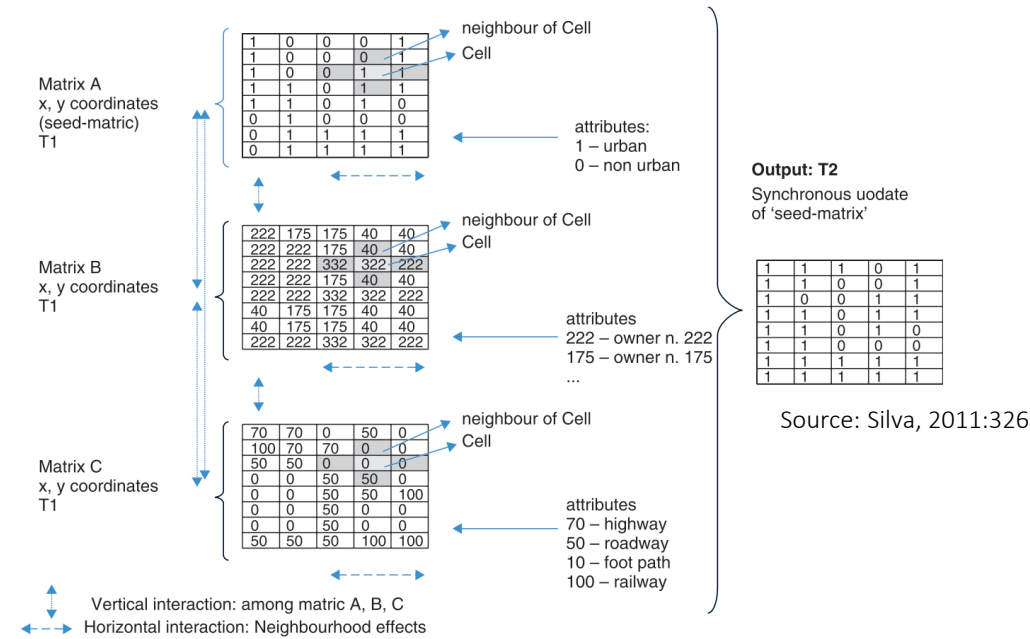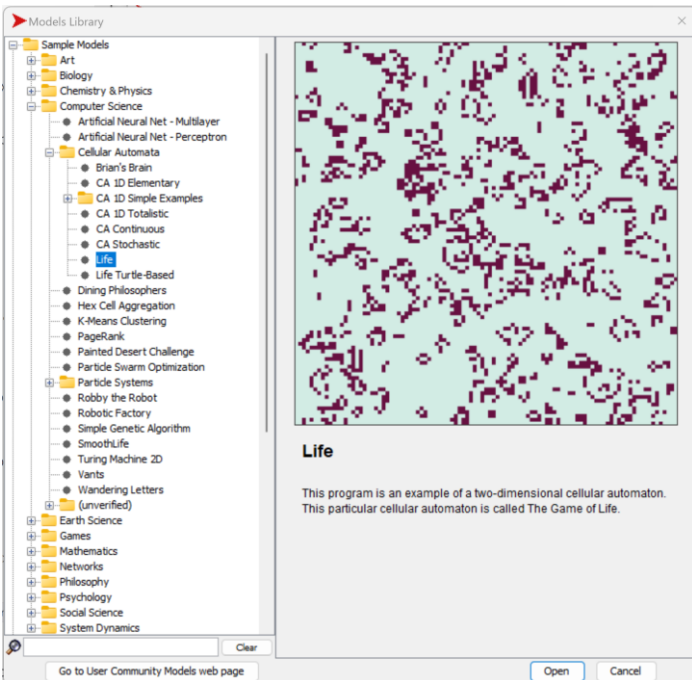https://www.sciencedirect.com/topics/earth-and-planetary-sciences/cellular-automata

Matrix A
x, y coordinates
(seed-matric)
T1

neighbour of Cell
Cell

attributes:
1 – urban
0 – non urban

Output: T2
Synchronous uodate
of 'seed-matrix'

Matrix B
x, y coordinates
T1

neighbour of Cell
Cell

attributes
222 – owner n. 222
175 – owner n. 175
...

Source: Silva, 2011:326

Matrix C
x, y coordinates
T1

neighbour of Cell
Cell

attributes
70 – highway
50 – roadway
10 – foot path
100 – railway

Vertical interaction: among matric A, B, C
Horizontal interaction: Neighbourhood effects

FIGURE 22.3 The cellular environment.

Good example of CA:
Conway's Game of Life

10

Cellular Automata (CA)

SLEUTH Urban Growth Model
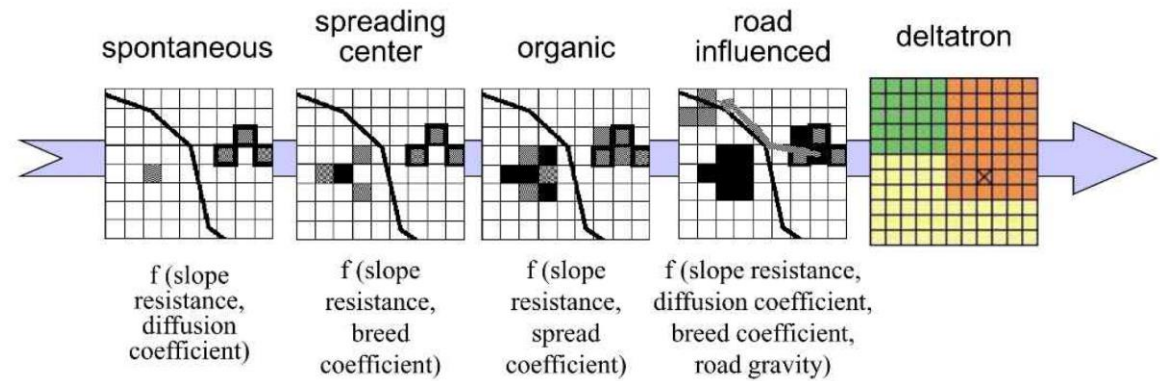
Source: Clarke., 2019

A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area

K C Clarke, S Hoppen
Department of Geology and Geography, Hunter College, The City University of New York
Graduate School and University Center, 695 Park Avenue, New York, NY 10021;
e-mail: kclarke@geog.UCSB.EDU

L Gaydos
US Geological Survey, EROS Data Center, NASA-Ames Research Center, Moffett Field,
CA 94035; e-mail: lgaydos@mail.arc.nasa.gov
Received 23 January 1995; in revised form 24 July 1995

Complexity, Emergence and Cellular Urban Models: Lessons Learned from Applying Sleuth to Two Portuguese Metropolitan Areas

ELISABETE A. SILVA[1,*] & KEITH C. CLARKE[2]

[1]Lisbon Technical University CESUR, Instituto Superior Técnico Lisboa, Portugal, [2]Geography Department,
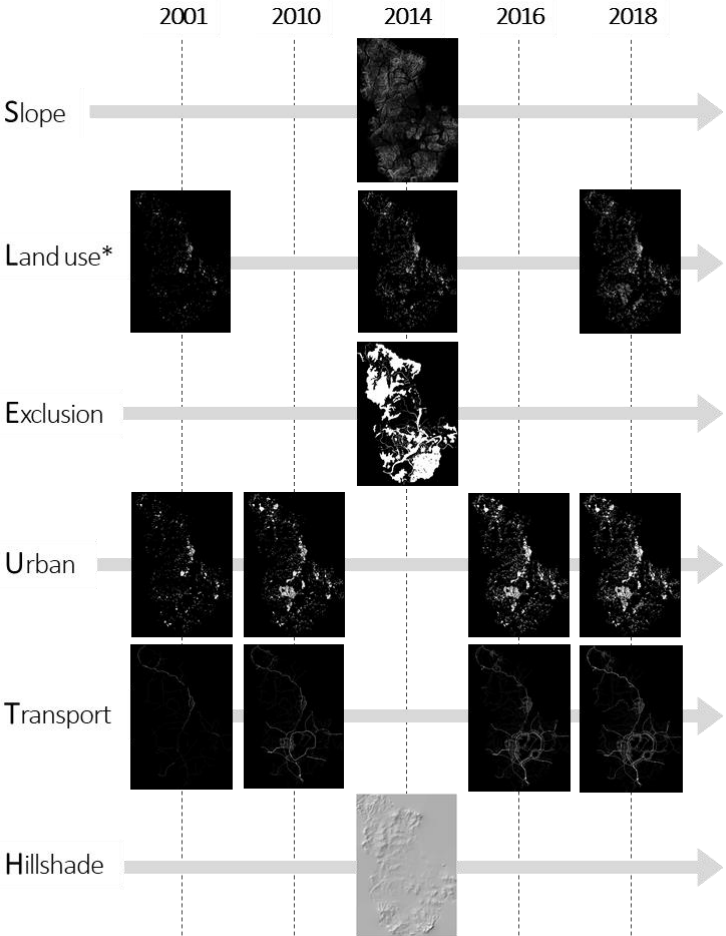University of California Santa Barbara, Santa Barbara, USA.

## Input layers of NL-SLEUTH-LUTI (30*30m raster)

Note: Land use maps are not included in SLEUTH because the model concerns non-urban → urban only. Instead, building use is used to calculate "mixed-use" as a variable for resident behaviour.

Source: Kwon et al., forthcoming a

Agent-Based Modelling (ABM)

NetLogo

← Spatial agents

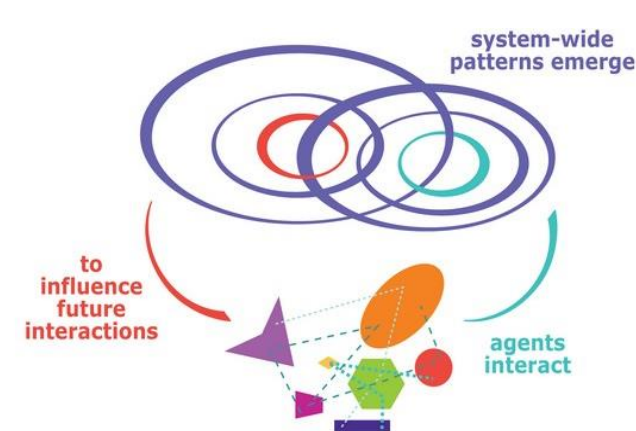← A-spatial agents

Source: Izquierdo et al., 2019

- ABMs assess the impact of autonomous agent behaviours on complex systems based on a set of behavioural rules

  - In urban planning, often used to link the physical environment and socio-economic data with agent behaviour to simulate the change of a city over time

  - Agents can represent various actors (land parcels, trees, people, businesses, governments…) and their behaviour can be affected by and affect the urban space

Source: Miskinis (2009), Rebaudo, et al. (2011)
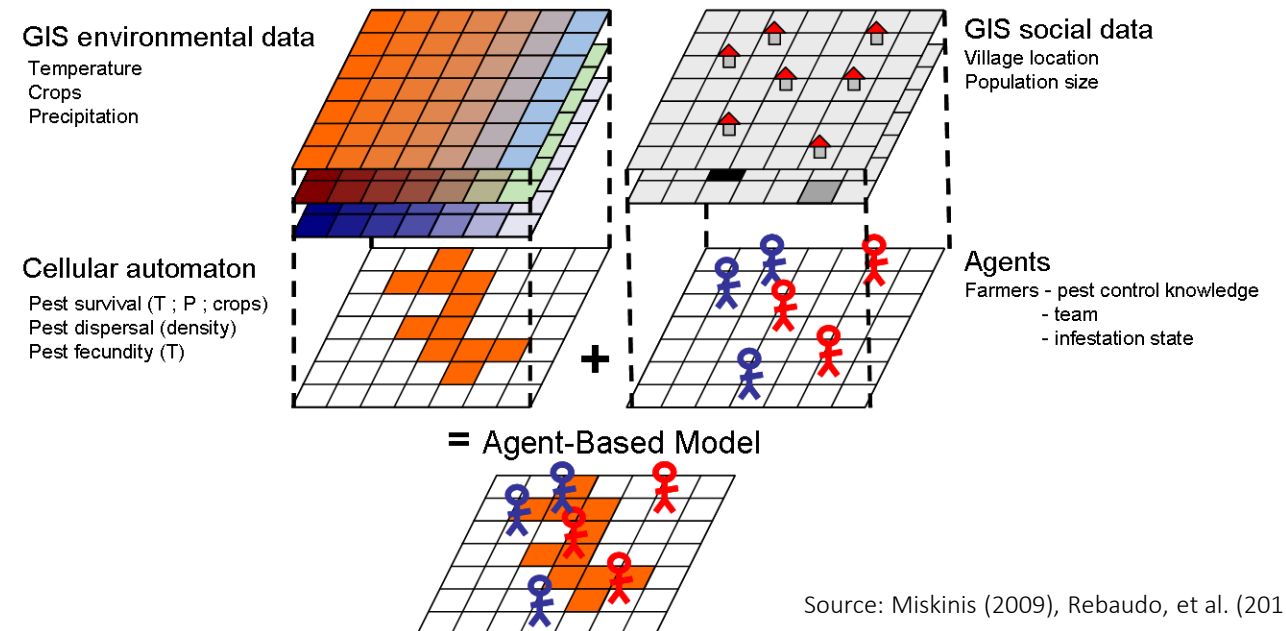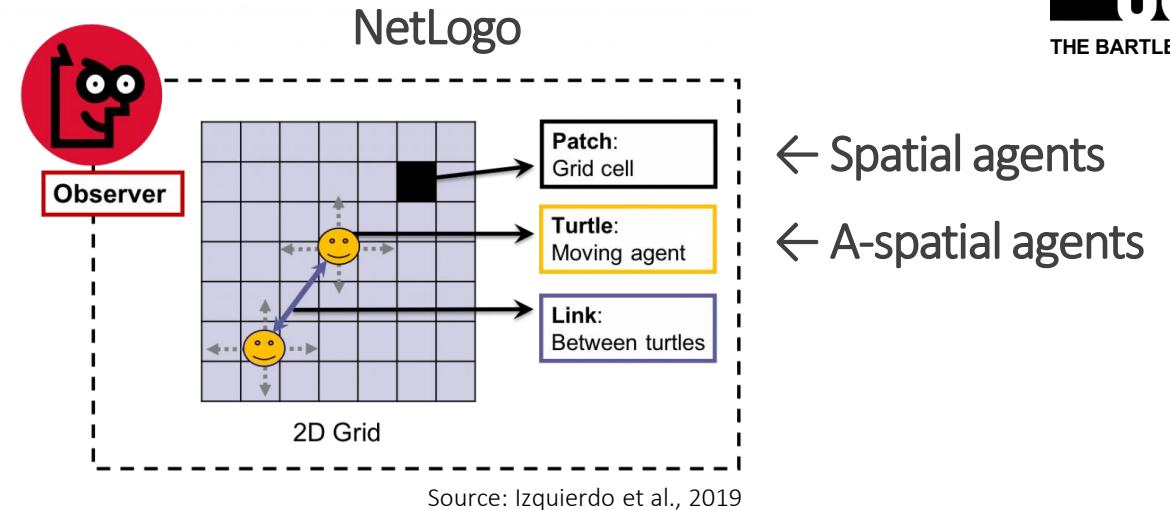
What is NetLogo?
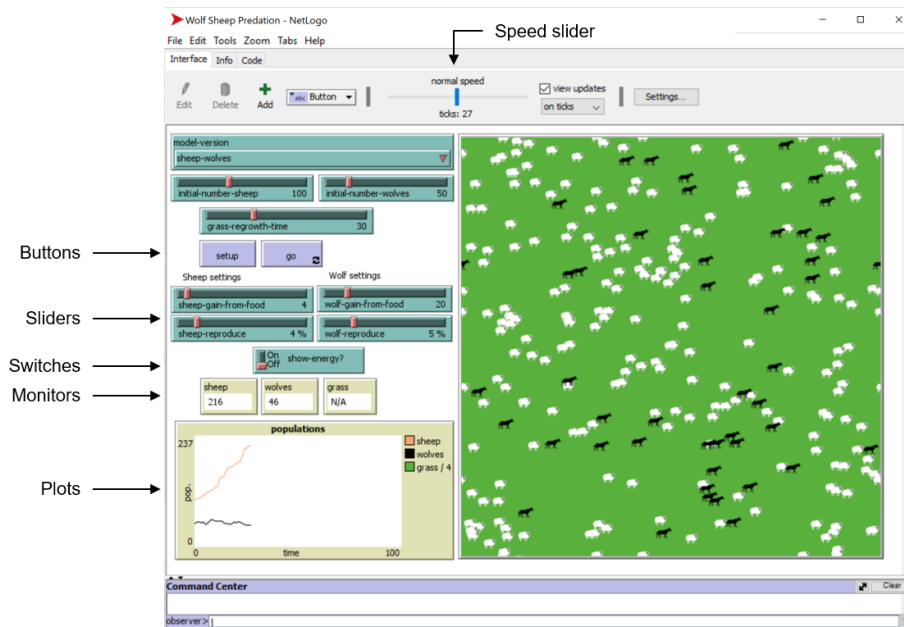
- NetLogo is a **multi-agent programmable modeling environment** for simulating natural and social phenomena
  - Well-suited for modeling **complex systems** developing over time

- Modelers can give **instructions to** hundreds or thousands of "agents" all operating independently (**autonomous agents**)
  - Making it possible to explore the connection between the **micro-level behavior** of individuals and the **macro-level patterns** that emerge from their interaction.
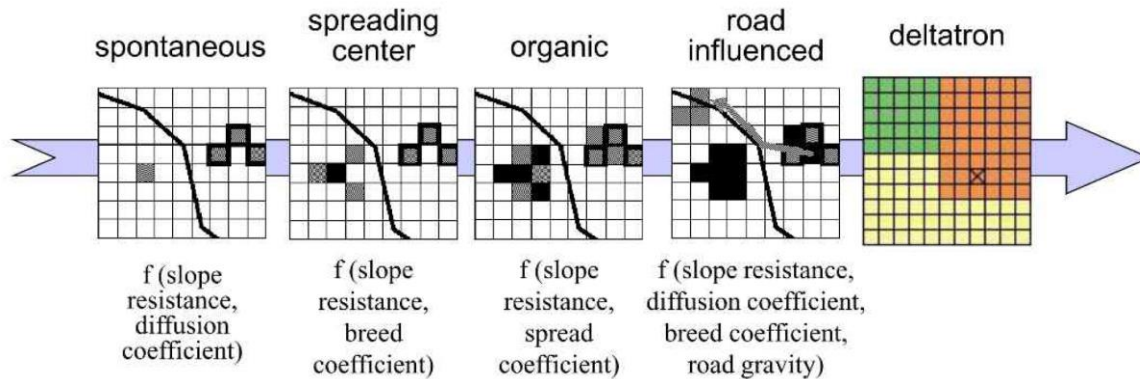
Source: (Wilensky, 2019)

Source: Human Systems Dynamics Institute, 2016

Cellular Automata (CA) and Agent-Based Modelling (ABM): Different Strengths

Cellular Automata
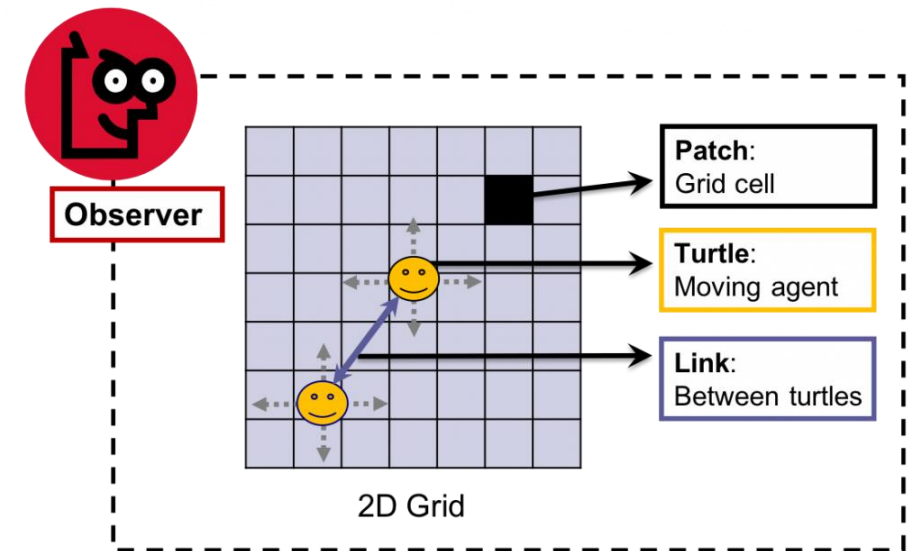### (e.g. SLEUTH urban growth model)

Particularly effective in modelling the spatial dynamics (e.g., land change)
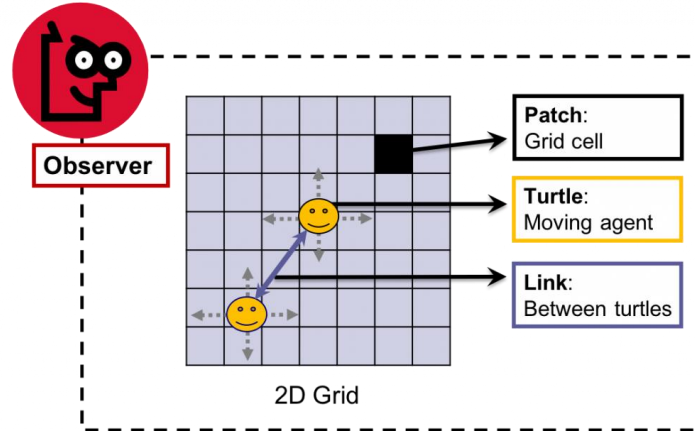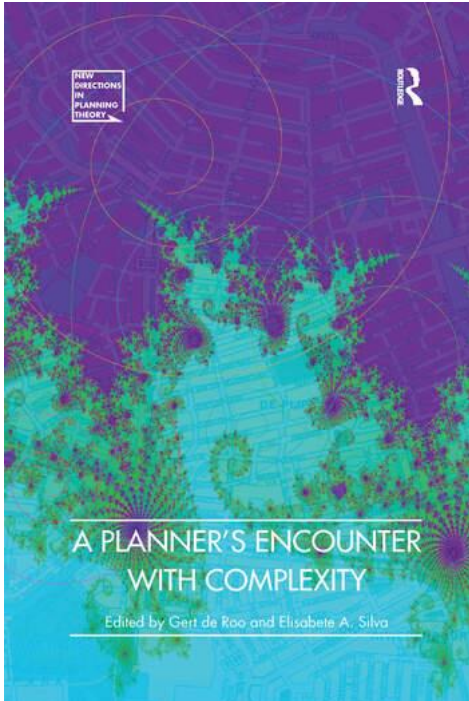

Source: Clarke., 2019

Agent-Based Model
(e.g. on NetLogo platform)

Particular strength in simulating human decision-making dynamics and interaction with the environment

Source: Izquierdo et al., 2019

Hybrid CA-ABM models

Lecture 1:

Any questions?

Dr Heeseo Rain Kwon

BSP Post-doctoral Research Fellow
Bartlett School of Planning, University College London
heeseo.kwon.10@ucl.ac.uk

THE BARTLETT

Now, it's time for NetLogo!

https://heeseorain.github.io/mini_module_abm/

16

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Clarke, K. C., Hoppen, S. and Gaydos, L. (1997) 'A self-modifying cellular automaton model of historical urbanization in the San Francisco Bay area', Environment and Planning B: Planning and Design, 24(2), pp. 247–261. doi: 10.1068/b240247.

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Silva, E.A., & Clarke, K. C. (2002). Calibration of the SLEUTH urban growth model for Lisbon and Porto, Portugal. Computers, Environment and Urban Systems, 26(2002), 525–552.

Silva, E.A, & Clarke, K. C. (2005). Complexity, Emergence and Cellular Urban Models: Lessons Learned from Applying Sleuth to Two Portuguese Metropolitan Areas. European Planning Studies, 13(1), 93–115.

Silva, E.A. (2011). Cellular Automata and Agent Base Models for Urban Studies: From Pixels to Cells to Hexa-dpi's. In X. Yang (Ed.), Urban Remote Sensing: Monitoring, Synthesis and Modeling in the Urban Environment (pp. 323–345). West Sussex, UK: Wiley-Blackwell.