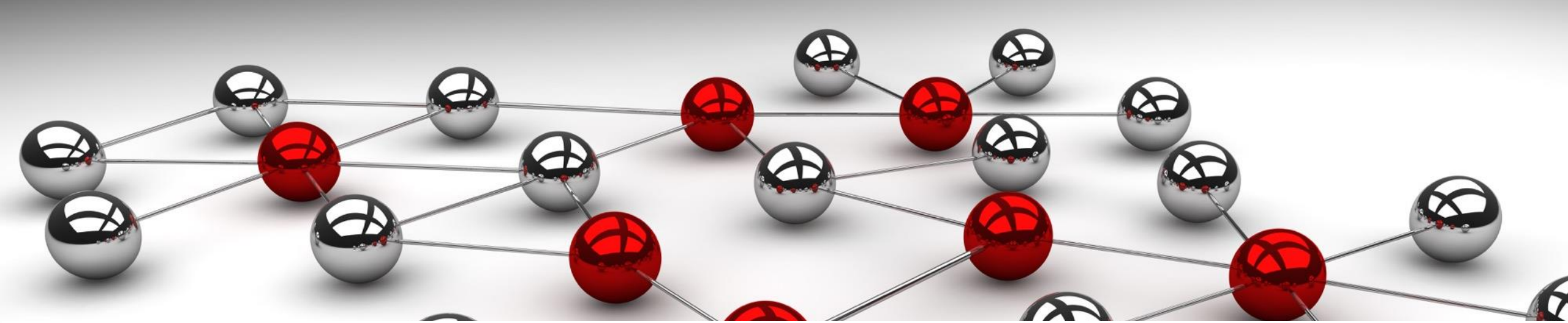


04 Introduction to Agent-Based Modelling (ABM) (Part I)

By NTU Complexity Institute

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

What is ABM?

Acronyms

- ABM: Agent-Based Modelling
- ABS: Agent-Based Simulation
- ABMS: Agent-Based Modelling and Simulation

What is ABM?

What is an agent?

- Autonomous decision-making entity (Bonabeau, 2002)
- Usually implemented as an AI software object
- ‘Proactive’ refers to the ability to set goals
- ‘Reactive’ is to respond to changes in environment
- ‘Interactive’ refers to working with or against other agents to achieve goals

Why Do We Use ABM?

- Natural description of problem in terms of agents
- System of agents is complex
  - Strategic interactions
  - Heterogeneity
  - Emergent collective behaviour

  } Not easy to build SD models
- ABM is a bottom-up approach
- Exploration
  - Better appreciate impact of poorly understood interactions
- Prediction
  - Scenario analysis for public policy

How to Build an ABM?

Ingredients

- Agent types (attributes such as gender, age, preferences, …)
- Action types (behaviours such as buying, selling, holding, …)
- Conditions

Observations

- Agent types ✔
- Action types ✔
- Conditions?

Interviews and surveys

- Agent types ✔
- Action types ✔
- Conditions ✔

Level of Detail

Number of agent types

- Can we group agents?

Number of actions

- Can we group actions?

Number of conditions

- Are there combinations of conditions?

Thomas Schelling
(1921–2016)

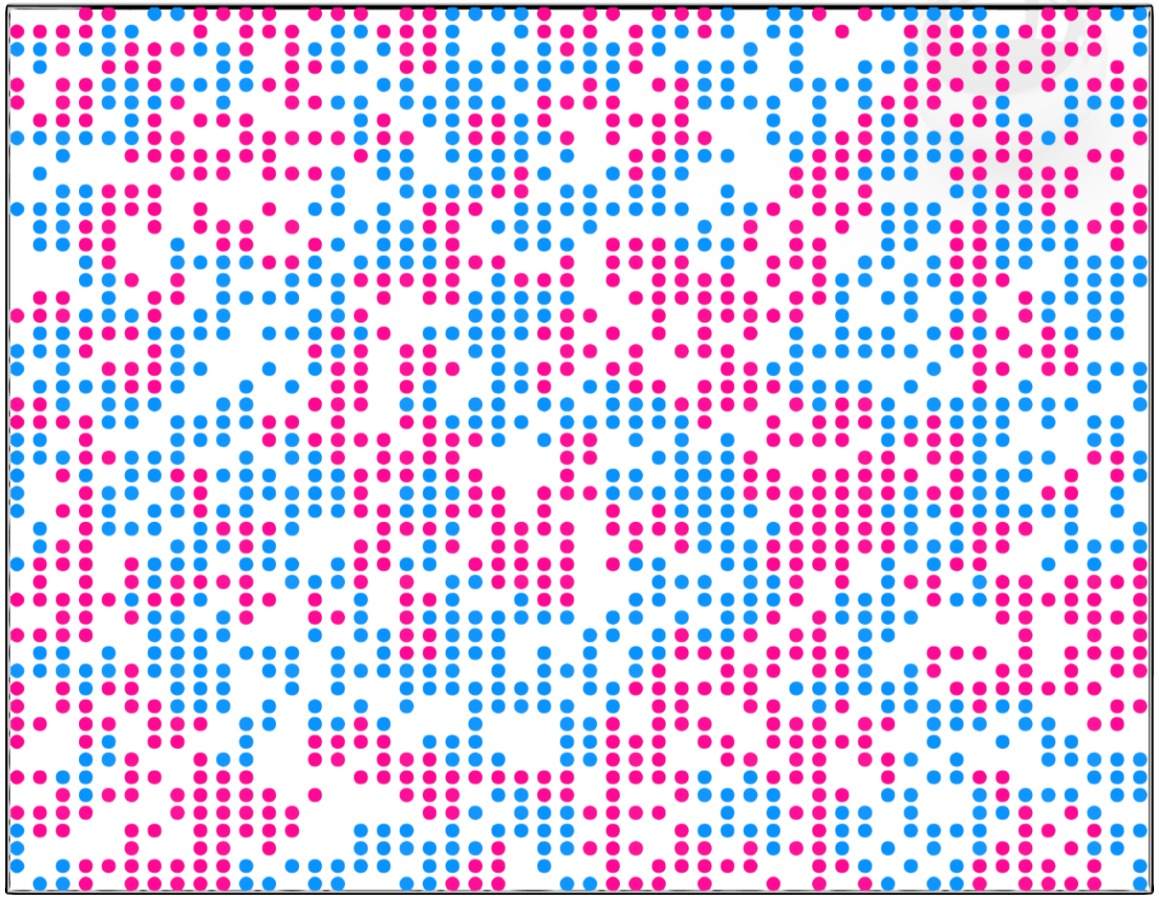
2005 Nobel Prize winner in economics

Simple Example of ABM: Thomas Schelling's Model

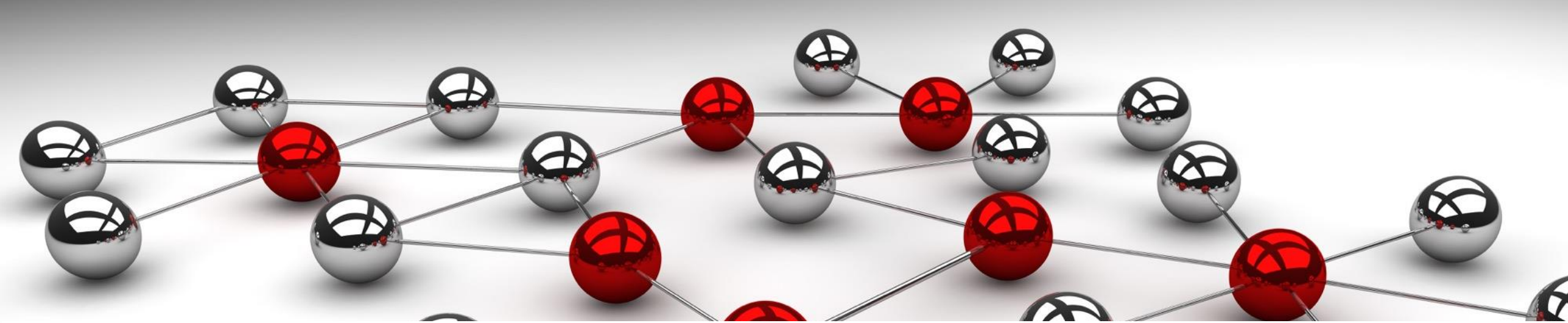
Rule: If fewer than fraction *p* of neighbours are of the same colour, move to a random vacant site.

Segregation persists even when *p* becomes vanishingly small!

Schelling Model with two colours: Final State with Happiness Threshold 30%



Segregated neighbourhoods



04 Introduction to Agent-Based Modelling (ABM) (Part II)

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How to Validate the ABM?

- Computer program must do what the model prescribes
- Verification problem
- For both exploratory and predictive ABM
- E.g., In a simulation of Schelling's model, an unhappy agent at $r = (x, y)$ is identified:
  - According to the model, the agent will move to a random vacant site $r' = (x', y')$. $r = (x, y)$ will now be vacant
  - The program creates a new agent at $r' = (x', y')$ but unhappy agent at $r = (x, y)$ remains
  - Implementation error must be corrected

How to Calibrate the ABM?

For ABM to be predictive, it must calibrated by using:

- Aggregate (macroscopic) data
  - E.g., For Schelling's model, we can measure an aggregate segregation index from real neighbourhoods, then adjust parameter *p* in model for simulations to produce same aggregate segregation index
- Mesoscopic data
  - E.g., For Schelling's model, Fourier transform $n(x, y)$ for real neighbourhoods to get $N_0(k_x, k_y)$. Then adjust parameter *p* in model until simulations produce $N(k_x, k_y)$ that best fits $N_0(k_x, k_y)$
- Microscopic data
  - E.g., For Schelling's model, track the relocation histories of individual households, then adjust parameter *p* in model until simulations produce best matching set of simulated relocation histories

Microscopic data is necessary if *p* is different for different households (heterogeneity).

Examples of Calibration

Show the graph of index of dissimilarity for Schelling's model

Show real-world index of dissimilarity as horizontal line to back out *p*

How to Validate ABM against Additional Data?

Testing calibrated ABM against additional data:

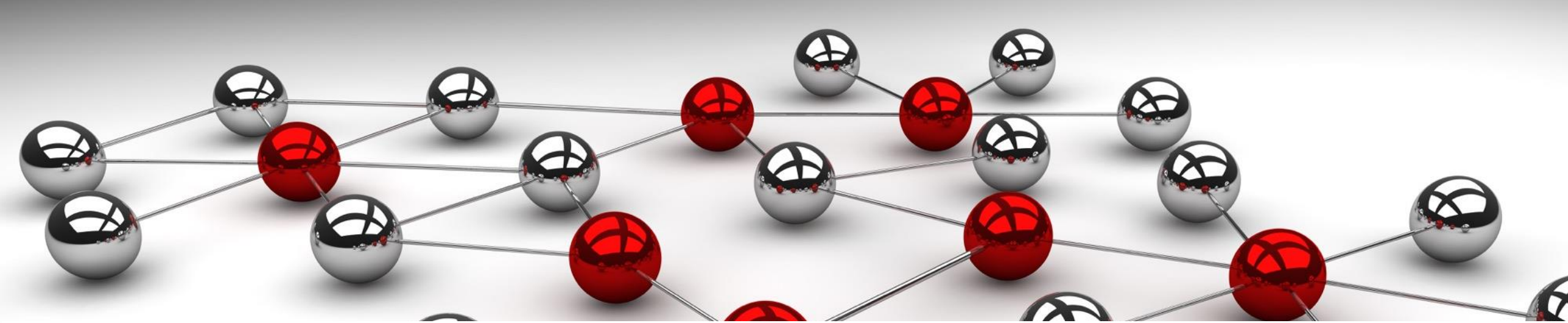
- Macroscopic data
- Mesoscopic data
- Microscopic data

Depending on purpose of ABM, the model can be calibrated against microscopic/mesoscopic data, but validated against macroscopic data

- Training data can be more detailed and more intrusive compared to operational data

Examples of Complex ABM

Feature the MRT + bus model developed by IHPC



04 Introduction to Agent-Based Modelling (ABM) (Part III)

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ABM for Policy Assessment

Risk assessment under different scenarios

- Test prevention, intervention and mitigation before actual events occur
- Synthetic futures for foresight exercises

Mechanistic understanding

- Change behaviours of agents to achieve desired outcomes and avert undesirable ones

Inform measurement of microscopic variables

- Identify the critical microscopic variables for given outcome
- Measure these in real life

Examples of ABM Platforms

NetLogo: https://ccl.northwestern.edu/netlogo/

Swarm: http://www.swarm.org/wiki/Main_Page

Repast: http://repast.sourceforge.net/repast_3/

MASON: http://cs.gmu.edu/~eclab/projects/mason/

Acknowledgements

- Slide 7: Photo of Thomas Schelling, extracted from Flickr: https://www.flickr.com/photos/newamerica/4525833911 by New America: https://www.flickr.com/photos/newamerica/ under CC BY 2.0: https://creativecommons.org/licenses/by/2.0/
- Slide 8: Image generated with Python codes. Retrieved April 17, 2017, from https://www.binpress.com/tutorial/introduction-to-agentbased-models-an-implementation-of-schelling-model-in-python/144.