# CASA0011

# Monday 8th January, 14:00 – 17:00

**PLEASE CHECK IN**

using the SEAtS Mobile App

# CASA0011: Agent-Based Modelling for Spatial Systems


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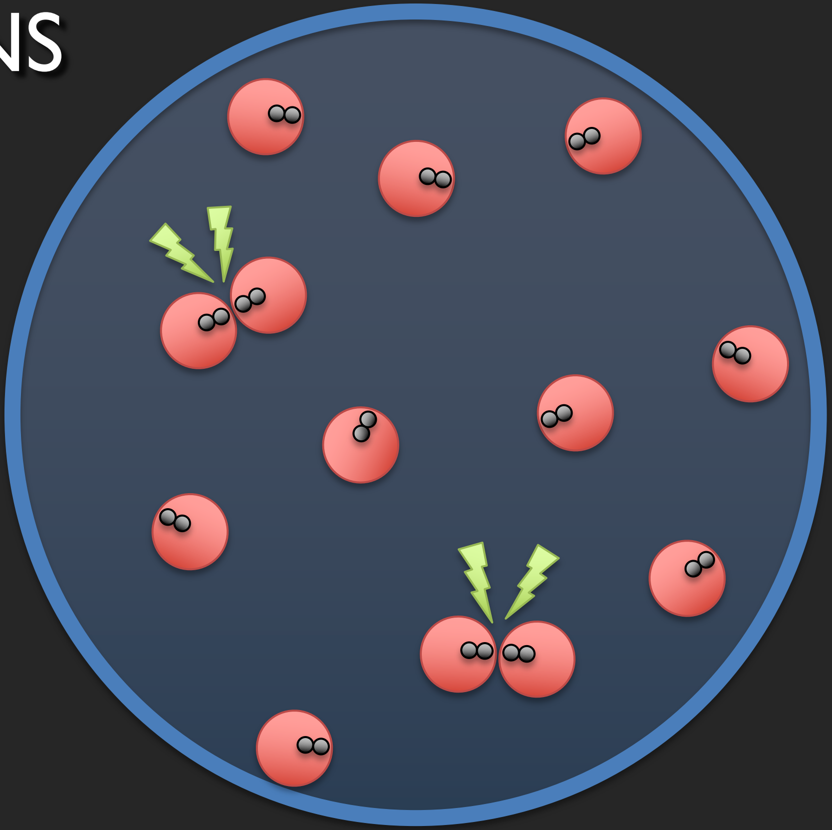
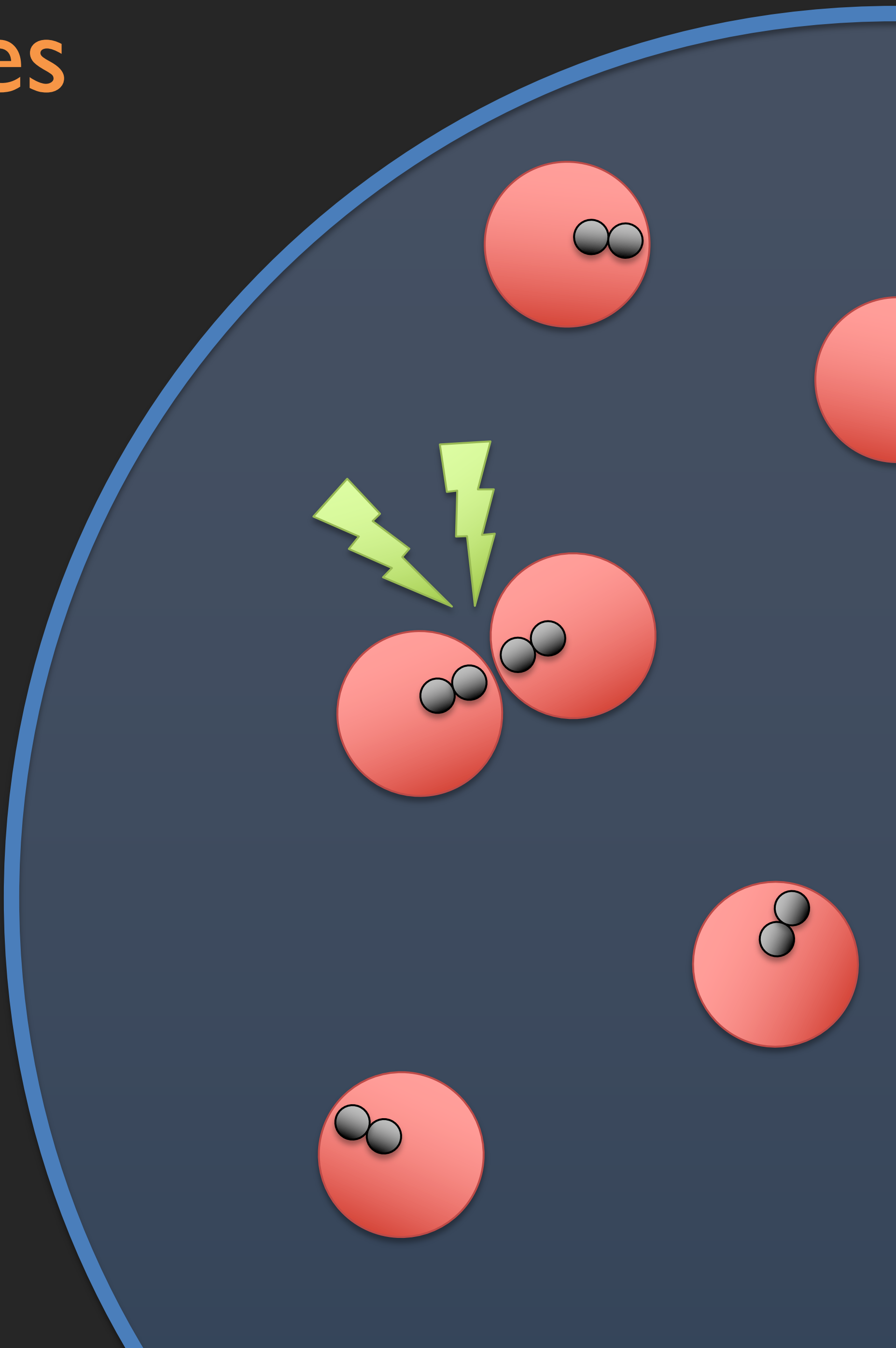


# Session Objectives

1. Understand the structure and focus of the course.

2. Understand what is meant by the term "complexity"

3. Be able to define an agent-based model



# Course Objectives

You should...

1. understand the principles of agent-based modelling (ABM)

2. be able to describe the type and range of systems to which ABM can be profitably and appropriately applied

3. be able to conceptualise and model urban systems with complex dynamics

4. show evidence of being able to translate these understandings into the practical methodology of modelling

| | |
|---|---|
| **Week 1:** | **Introduction to ABMs** |
| **Week 2:** | Cellular Automata |
| **Week 3:** | ABM Methodology |
| **Week 4:** | Agent Behaviours |
| **Week 5:** | ABMs as Research Tools |
| **READING WEEK** | |
| **Week 6:** | Testing ABMs |
| **Week 7:** | Presenting Results |
| **Week 8:** | Forecasting & Prediction |
| **Week 9:** | Traffic Modelling |
| **Week 10:** | Transportation Modelling |

# The ABM Course

# Course Communication

- Email
- Moodle Feedback – submit anonymous questions/comments for us to address in the next lecture.
- Slack – join the channel to discuss material and collaborate with other students.

# Coursework

2 pieces, each worth 50% of your final mark.

- CW1
  - Analysing the Sugarscape model
  - due Friday, 23rd February

    (the Friday after reading week).
- CW2
  - Build a model and write an ODD description of it
  - due Tuesday, 23rd Apr

    (the second day of Term 3).

# LECTURE 1

## An Introduction to Agent-Based Modelling

# What do we mean when we say “complexity”?

## The whole is more than the sum of the parts

"complexity arises when the dependencies among the elements [of a system] become important. In such a system, removing one such element destroys system behavior to an extent that goes well beyond what is embodied by the particular element that is removed”

- Miller and Page, *Complex Adaptive Systems*

# Complex Systems

Driven by Individual Behaviour: complex phenomena are best understood as a function of the behaviour of all interacting parts

- How does each individual play a part in the system?
- How does individual behaviour change reflect in the system?
- How do individuals and systems interact to cause change?
- How do interactions vary in respect to other conditions?

Macroscopic phenomena **emerge** through microscopic actions and interactions

# Complexity ≠ **Complicated**

Behaviours can emerge from **simple, lower-level rules**, rather than from many different or complicated rules.

e.g.

- movement
- heterogeneity
- interaction
- individuals with limited information
- social networks
- emotion

System behaviour is characterised by **non-linear** actions and interactions

System contains **non-equilibrium processes**

Responses to actions may be **disproportionate**, not easily predicted through examination of macroscopic dynamics only

# Why does this idea matter?

complex worlds are *not* reducible, and hard to decompose - doing so can ruin the system

we can’t study parts in isolation

we can’t predict how our interactions with the system will influence it

Complex systems show patterns of function that have a **much higher robustness to failure and error** and a **higher adaptability** than conventional human engineered systems

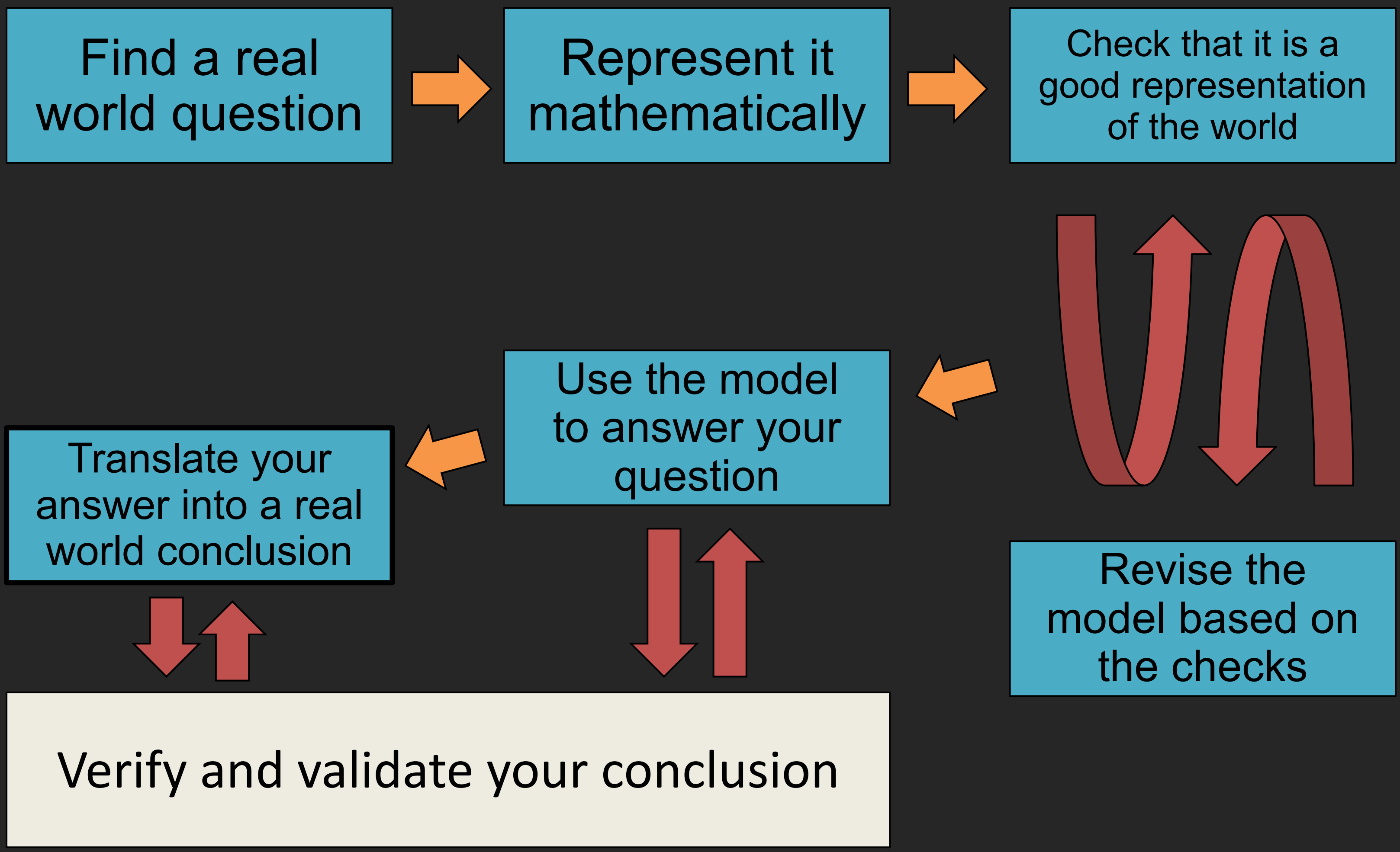
– Yaneer Bar-yam,
Unifying Principles in Complex Systems

# What is a model?

- “A model can be a **precise and economical statement of a set of relationships** that are sufficient to produce the phenomenon in question.” - Schelling, Micromotives and Macrobehaviour
  - "it is a 'model' because it reproduces the **essential features** of those other behaviors in a transparent way" p 83
- theory: "a cohesive set of **testable propositions** about a phenomenon" Miller and Page, Complex Adaptive Systems

A model "will yield interesting results only if the model behaves in the same way as the human system" - Gilbert

# Modelling: Key Principles



# SO…WHAT MAKES A MODEL “AGENT-BASED”?

# Agent-based models

Models in which **individual entities interact** with their environment and one another, such that their actions produce higher-level dynamics

These entities:

- Have internal states (e.g. wealth, speed, knowledge)
- Have rules of behaviour (e.g. trading, movement, sharing)
- Are autonomous (or semi-autonomous)

# Specifying an ABM

- Determine **what you want to measure about the system**
- Identify the **kinds of agents** present
- Identify the **environment** in which the agents are situated, and **any dynamics** affecting it
- Implement each kind of agent as a specific **object**, with **instance variables**
- Identify and implement the **interactions** between
  - agents of various kinds
  - agents and the environment (including activation order!)
- **Instantiate** the model with agents and environment, either drawn randomly from a distribution or from a data source

# Advantages of ABM

- Heterogeneous agents – replace representative agents, focus on distribution of behaviour instead of average behaviour
- Bounded rationality – possibility to include decision-making, limited information in an intuitive and accessible fashion
- 'Local' interactions – agent-agent interactions mediated by inhomogeneous topology (e.g., graph, social network, space)
- Focus on dynamics – paths to equilibrium and non-equilibrium processes
- Nonlinear dynamics – ease in incorporating trends which elude closed solutions

Each realisation exists as its own sufficiency theorem

*Thanks to Prof Rob Axtell for much of this slide!*

# Disadvantages of ABM

- Robustness of results
  - Artefacts – spurious correlation resulting from coding peculiarities; requires careful coding and extensive debugging to avoid!
  - Dependence on parameters – parameter sweeps and the 'curse of dimensionality'
- The problem of standards
  - More later on the challenges of code availability & docs
  - Docking with existing models
  - Publication of results
  - People are going to ask you to build one

*Thanks to Prof Rob Axtell for much of this slide!*

# TAKE A BREATHER!!!

Tutorial Session!

# GETTING STARTED WITH NETLOGO

# Step 1: Download NetLogo

https://ccl.northwestern.edu/netlogo/download.shtml

Also see

**Lecture and Workshop Material > General**

tab

# A Few Examples of ABMs

- Flocking – pure interaction, basically no environment
- Traffic Grid – movement, behaviour
- Virus on a Network – it doesn’t have to be physical space!

# The Muddy Field – A Simple Example

# EXPLORE ON YOUR OWN A BIT!

# MUSHROOM HUNT!