MONASH University
Information Technology

FIT5226

Multi-agent System & Collective Behaviour

Wk 1: Topic and Unit Overview

Bernd Meyer, March 2025

Teaching Team & Consultation

- **Prof Bernd Meyer**
  - **Chief Examiner**
  - **Consultation: see Moodle**

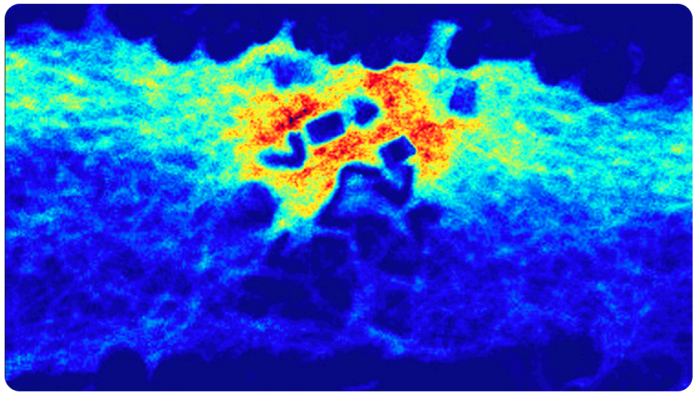
- **Unit Coordinator**
  - **your first point of contact for administrative questions**
  - **Yue Yang**
    consultation by appointment:
    <yue.yang1@monash.edu>

- **Tutors**
  - **Shenzhou Zhang (Stephen)**
  - **Esteban Larach Kaschel**
  - **Yasin Pathan**

Bernd Meyer

Data-intensive Computational Ecology

RESEARCH AREAS



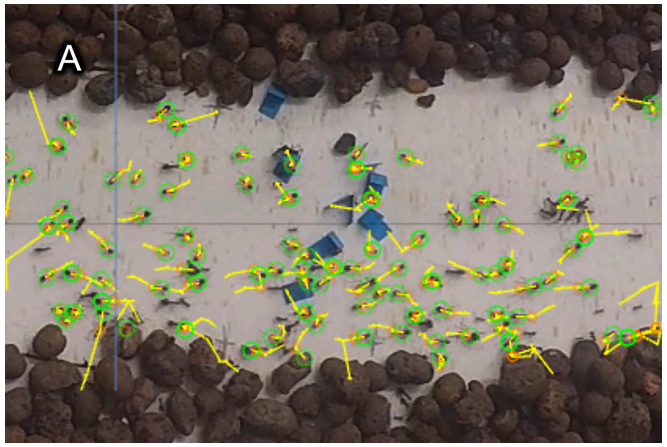
Collective Behavior

We develop mathematical and computational models to explain how groups of socially living animals achieve coorrdinated decision making and group behaviour

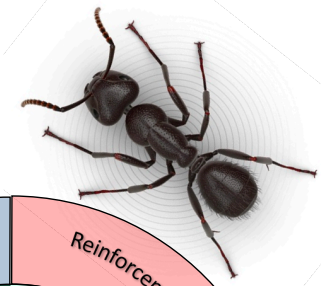
Animal Monitoring

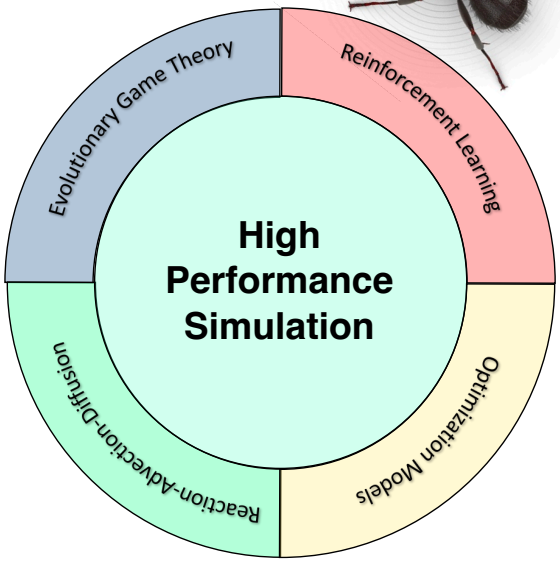
We develop AI-driven methods to monitor animal behavior and occurrence in the wild and in the lab

Data-Intensive Computational Ecology

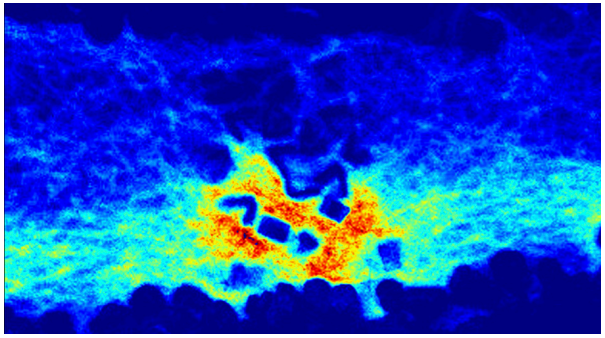


Lab Experiments





AI for Data Extraction



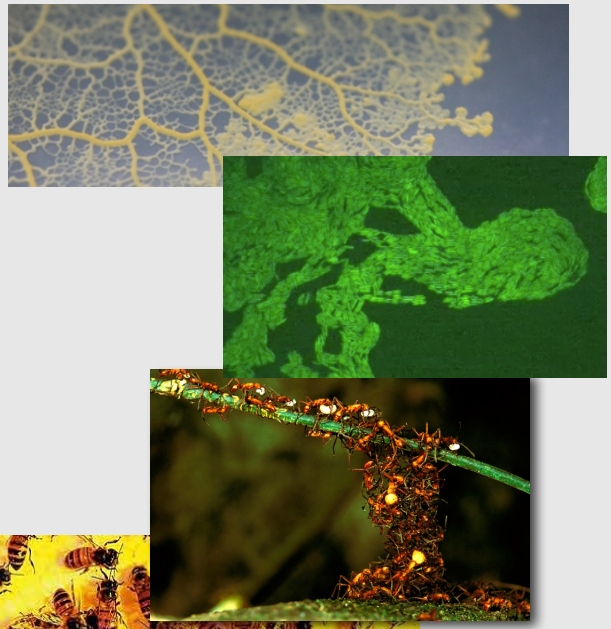
Mathematical Behaviour Modelling

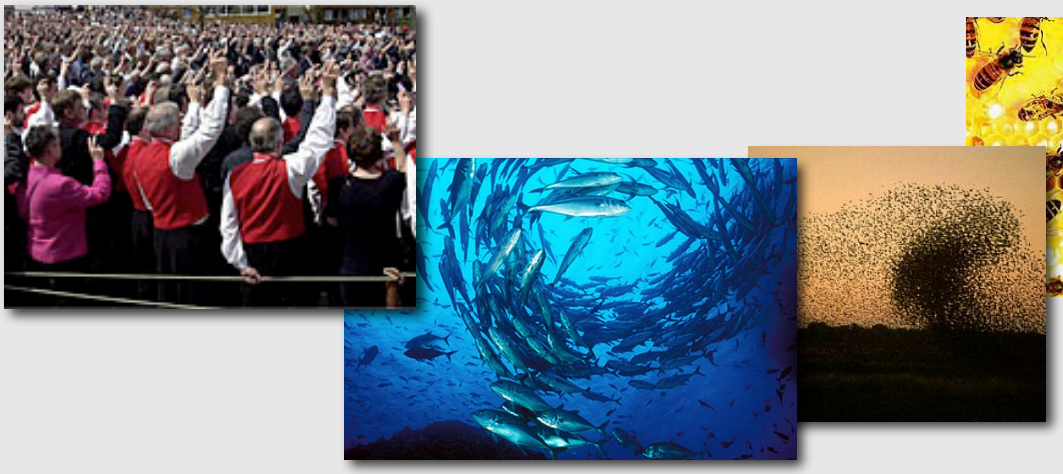
What we will discuss today

- **What do you hope to learn?**
- **What are Multi-Agent Systems?**
- **Main Approaches**
- **Unit Structure**
- **Assessment**
- **Literature**

“Natural” examples of Multi-Agent Systems

- **Biology**
  - Social Insects: **Ants**, **Bees**, Wasps, Termites...
  - **Bacteria** (eg Myxobacteria): Colonisation
  - Primitive Cellular Organisms (eg **Slime Molds**)
  - **Cell Migration**: Wound Healing, Tissue Formation
  - Bird Flocks, Fish Schools
  - Herds
- Economic Markets (Trendsetting, Hit & Flop Dynamics)
- Democratic Decisions





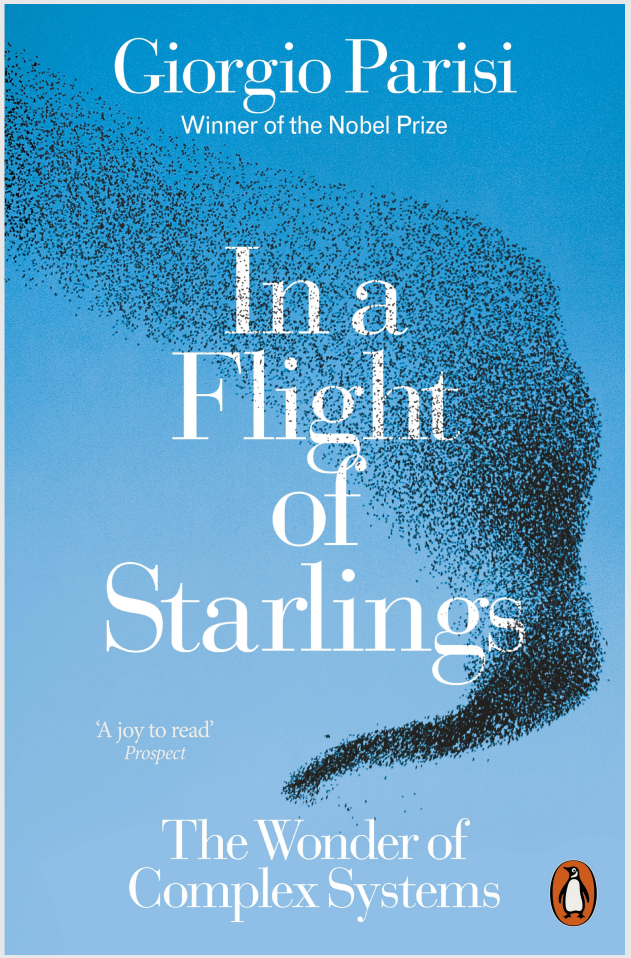
It’s not so simple…

Giorgio Parisi

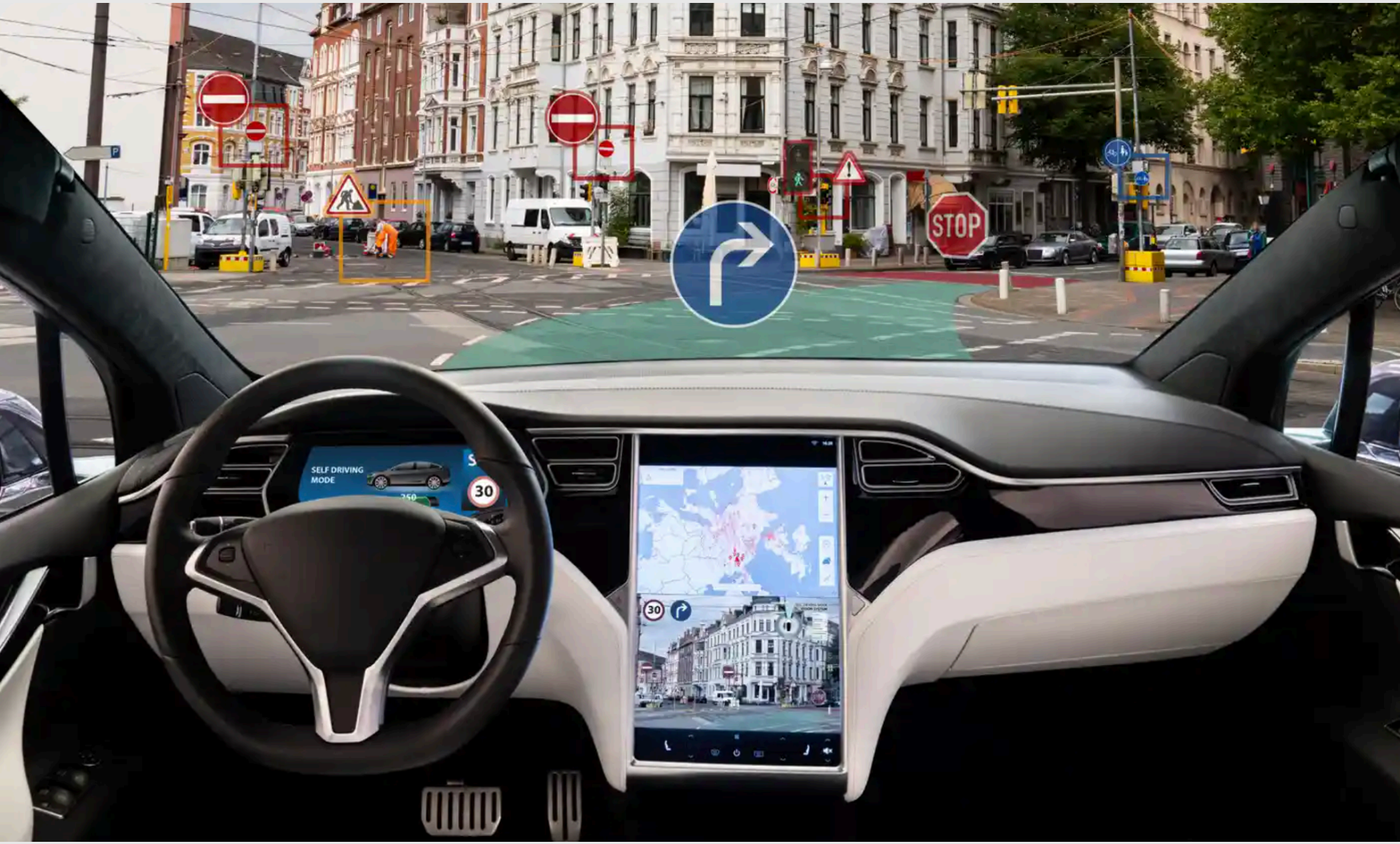
- *quantum field theory,*
- *statistical mechanics*
- *complex systems*

Nobel Price in Physics for

“the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales"

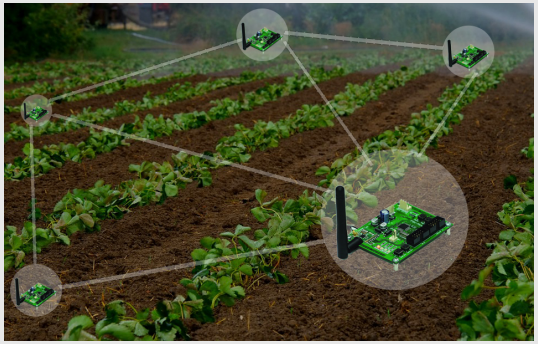


Engineering Examples



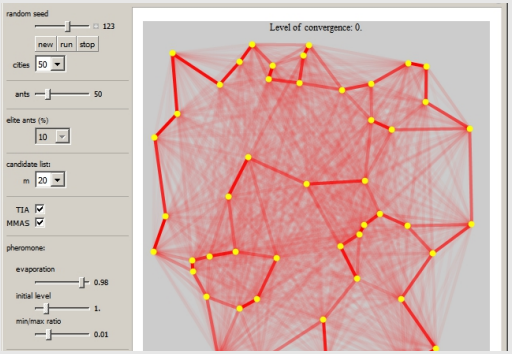
Engineering Examples

Swarm robots



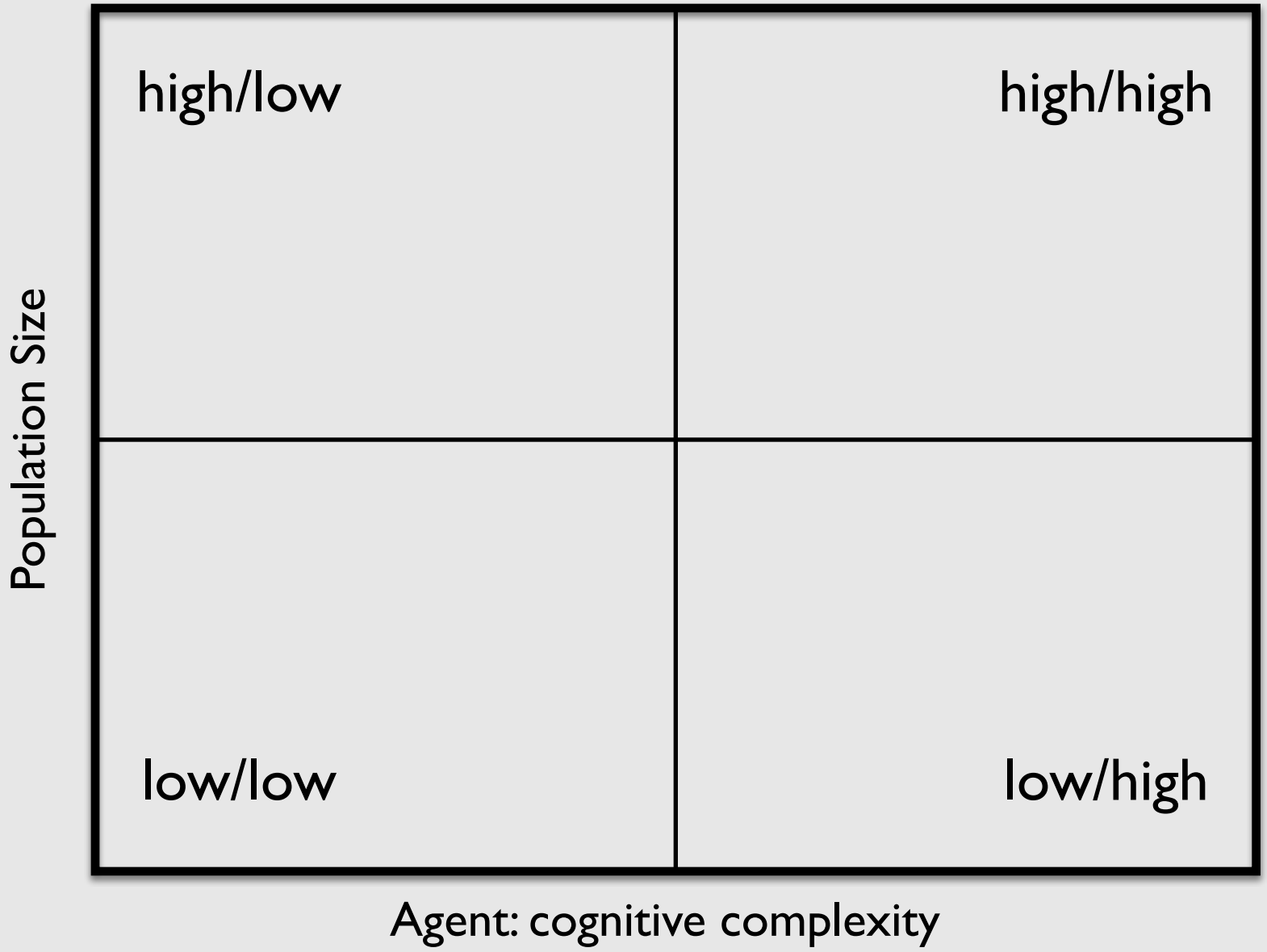
Autonomous sensor networks

Crowd & traffic control

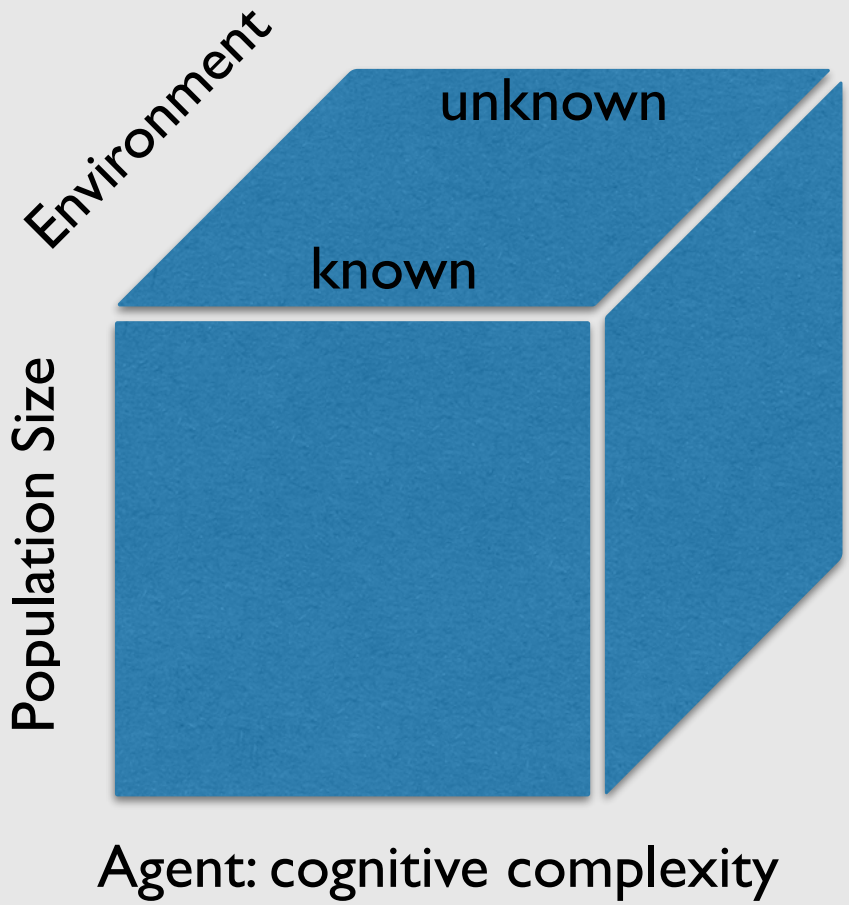


Automated Warehouses

MAS Complexity

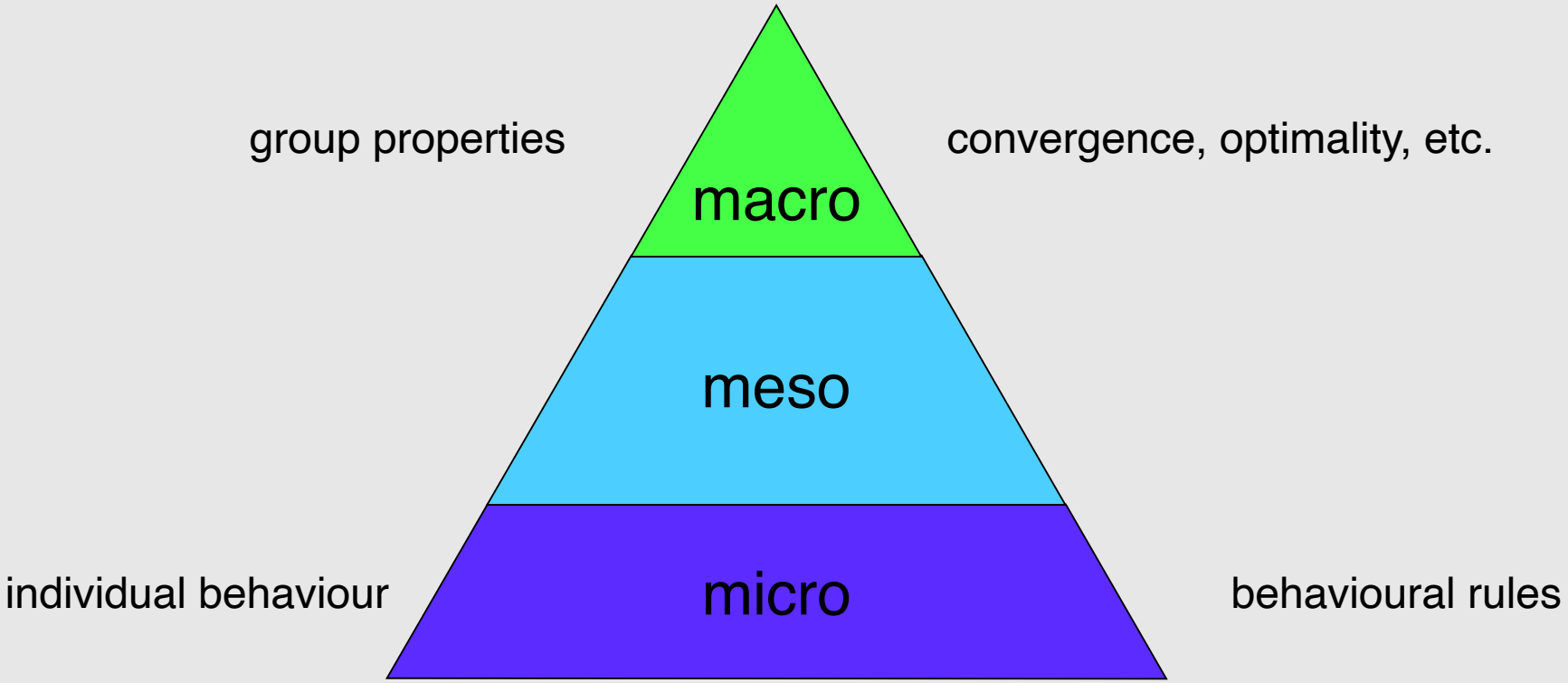


MAS Complexity



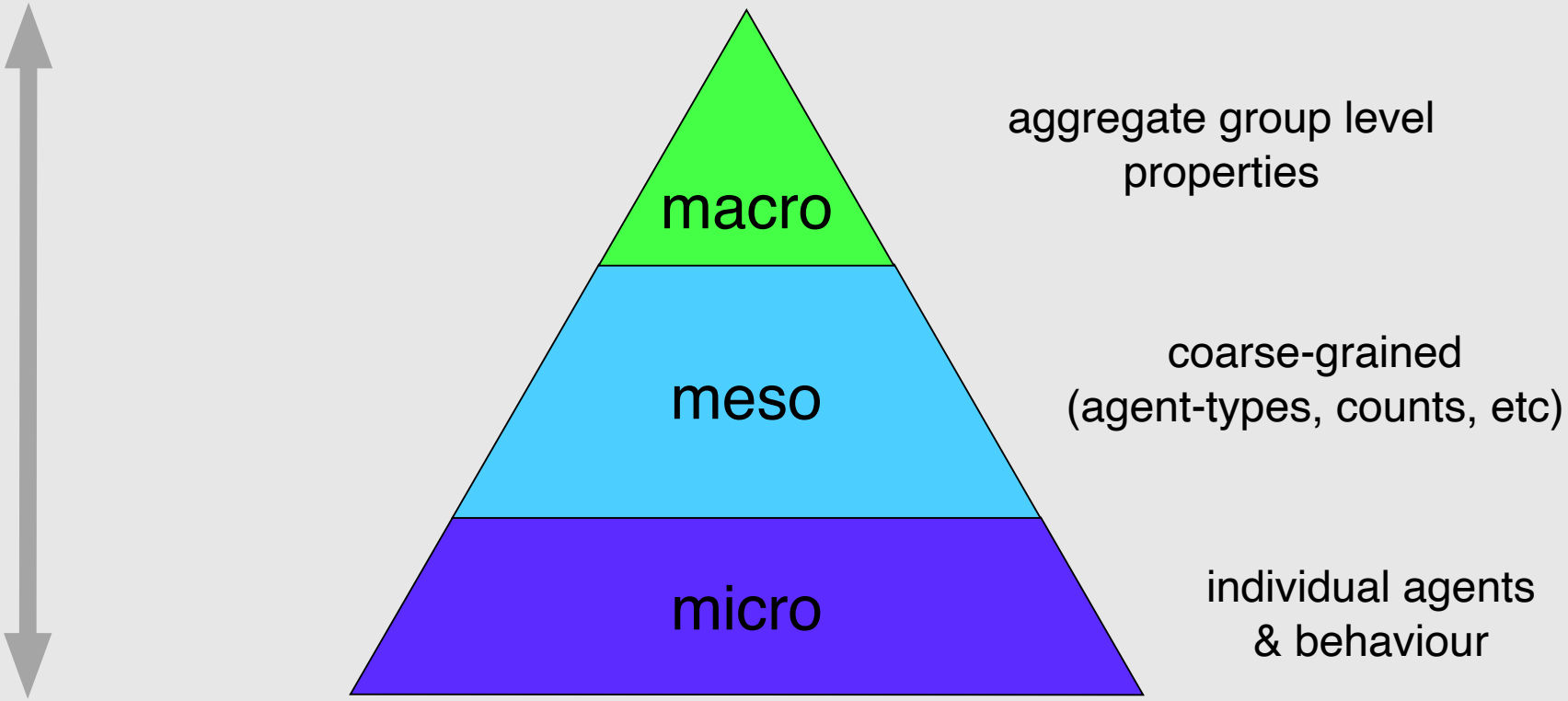
Do we have a model of the environment? Does the agent?

Individual Behaviour ➡ Group Behaviour

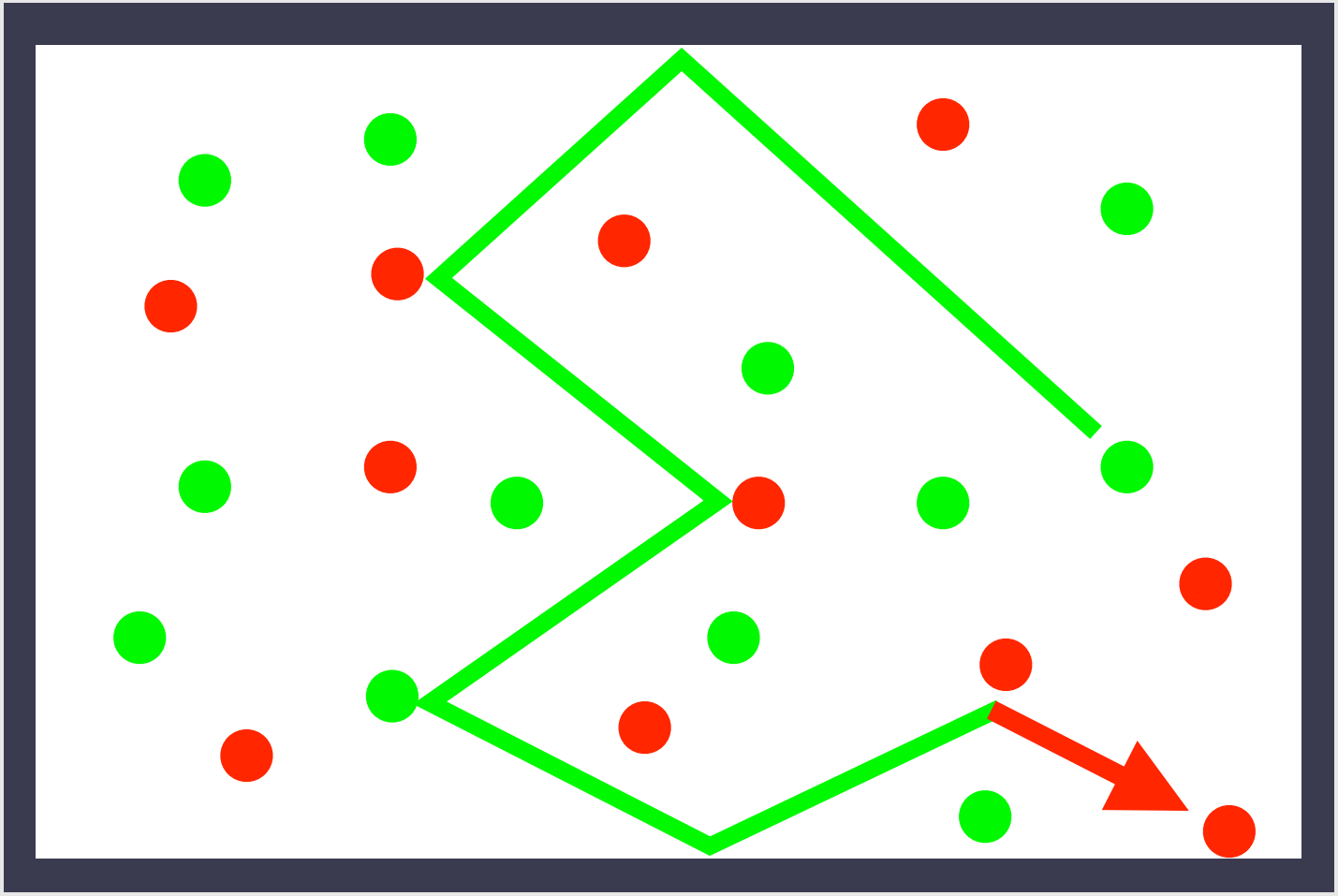


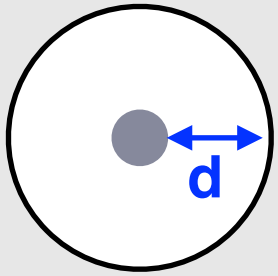
Example: Task Allocation in Animals, Humans, and Robots

The elusive Micro-Macro link



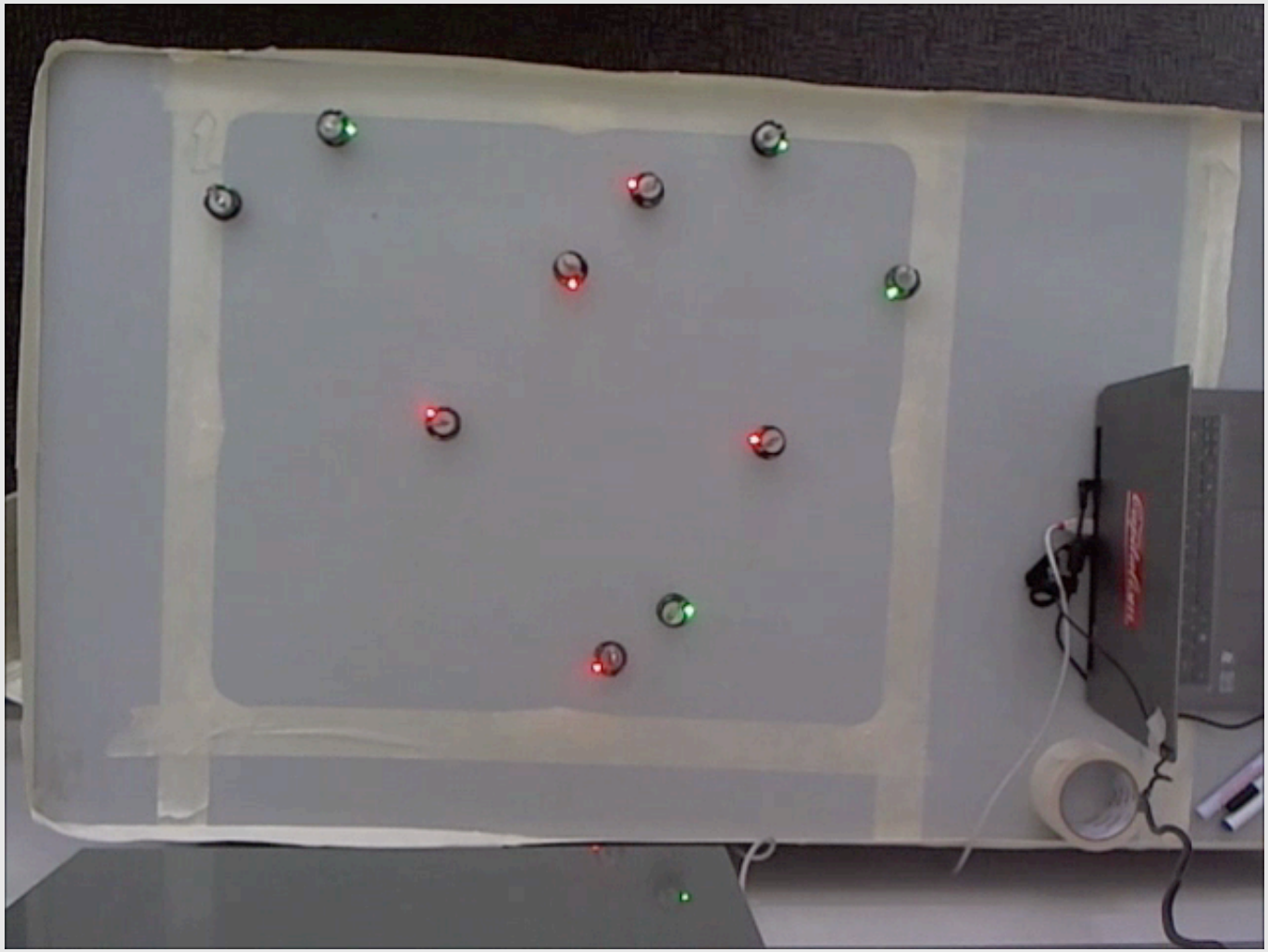
Example: majority consensus

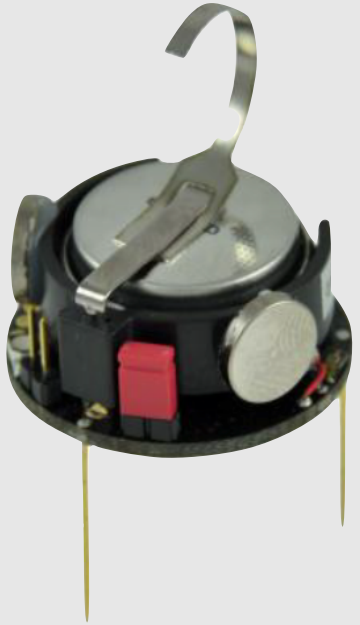




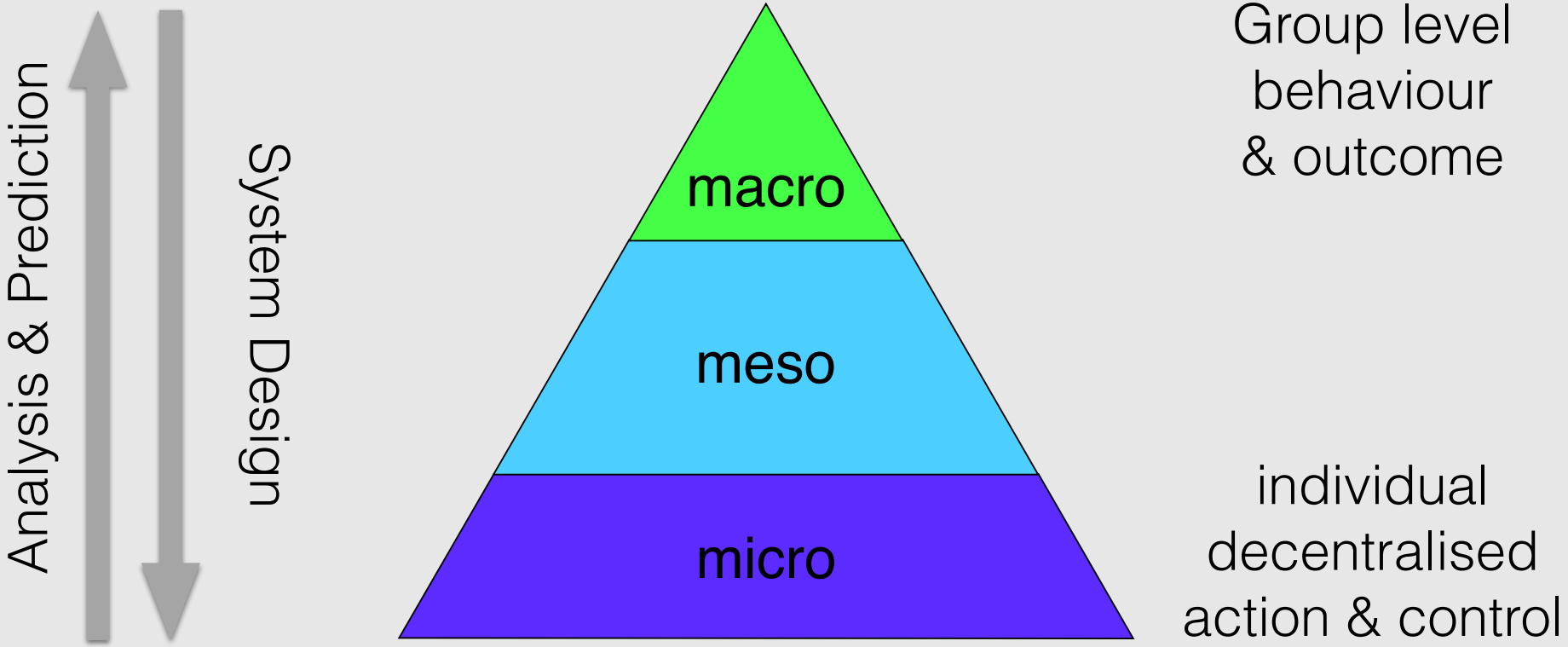
- relevant for some forms of *quorum sensing*

Experimental Set-up



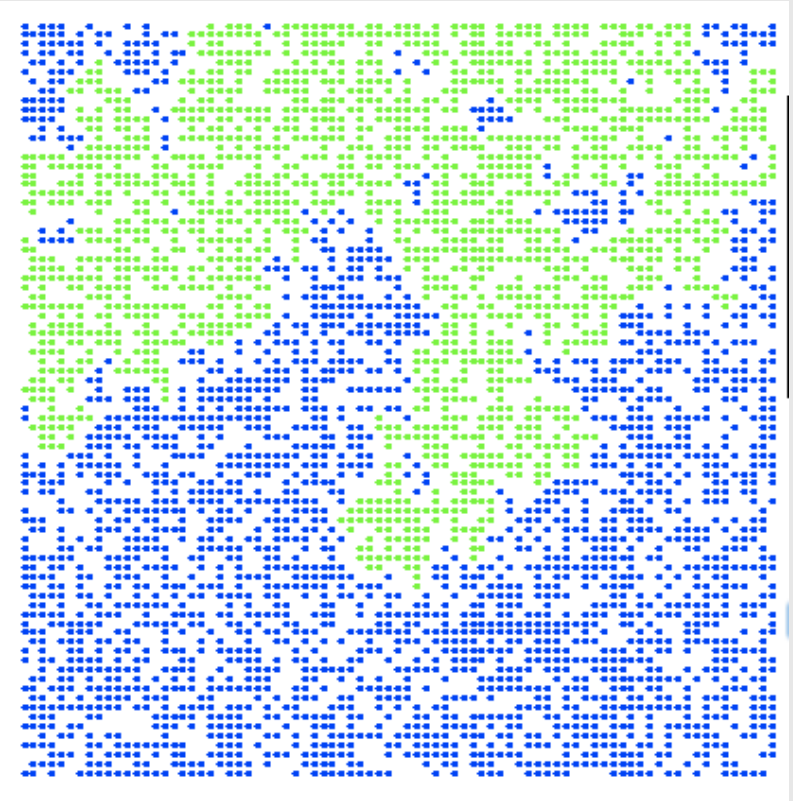


Two perspectives: Science vs. Engineering



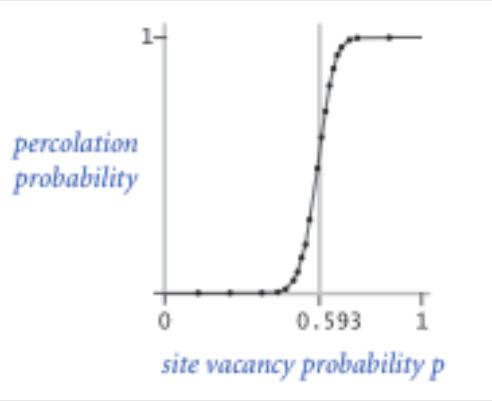
Multi-Agent Systems without intentional behaviour

Percolation clusters



http://www.physics.buffalo.edu/gonsalves/Java/Percolation.html

Percolation curve



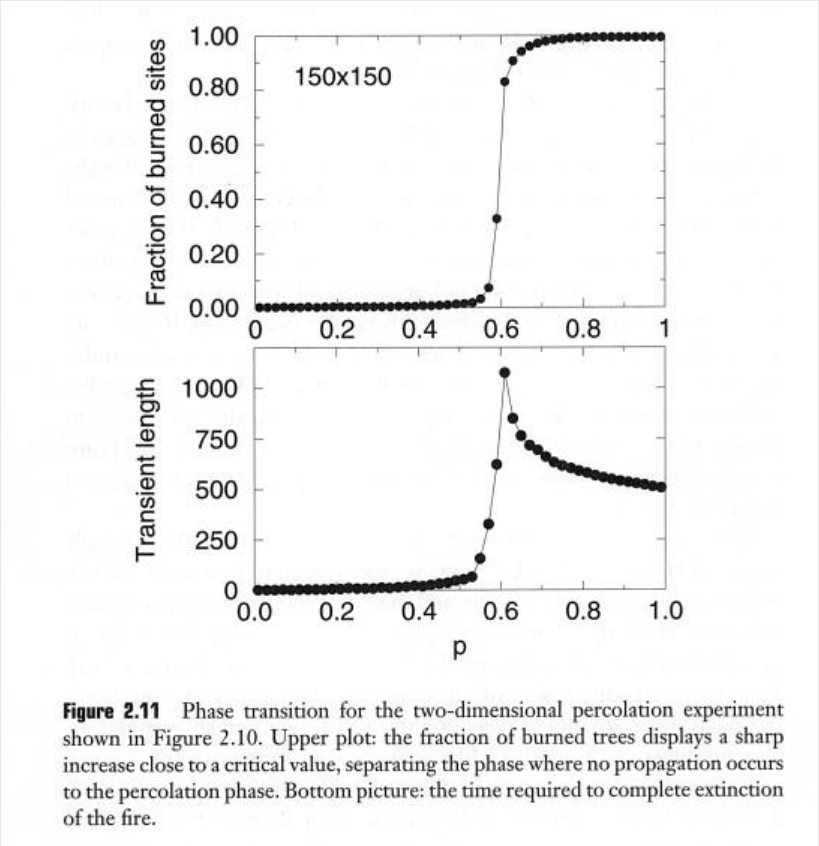
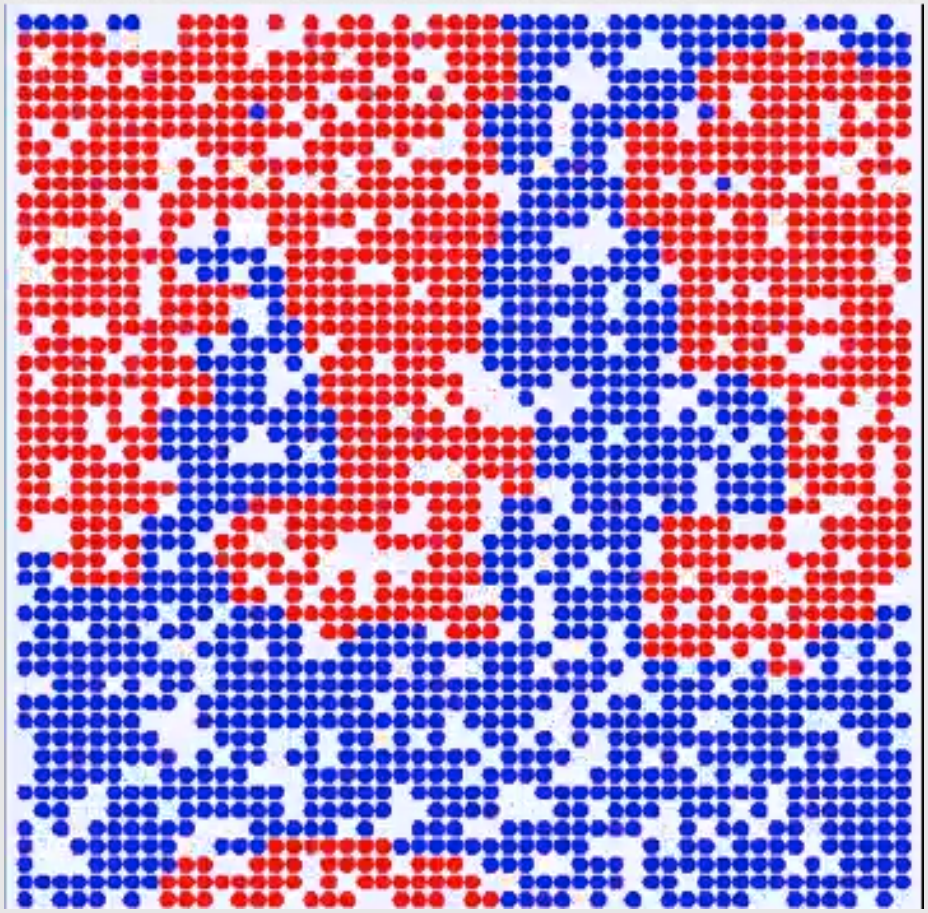


Figure 2.11 Phase transition for the two-dimensional percolation experiment shown in Figure 2.10. Upper plot: the fraction of burned trees displays a sharp increase close to a critical value, separating the phase where no propagation occurs to the percolation phase. Bottom picture: the time required to complete extinction of the fire.

Sole/Goodwin: Signs of Life

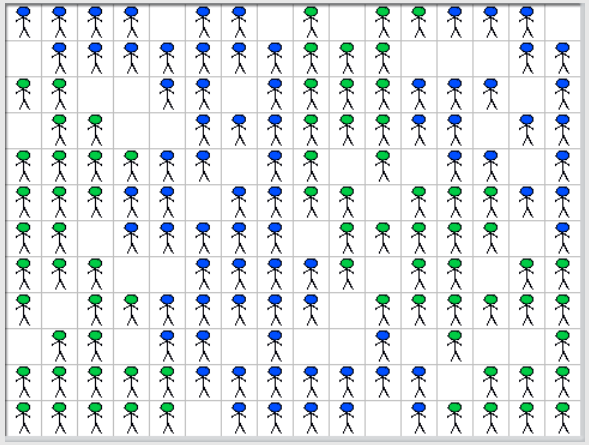
Acting with Intention: Schelling Segregation Model



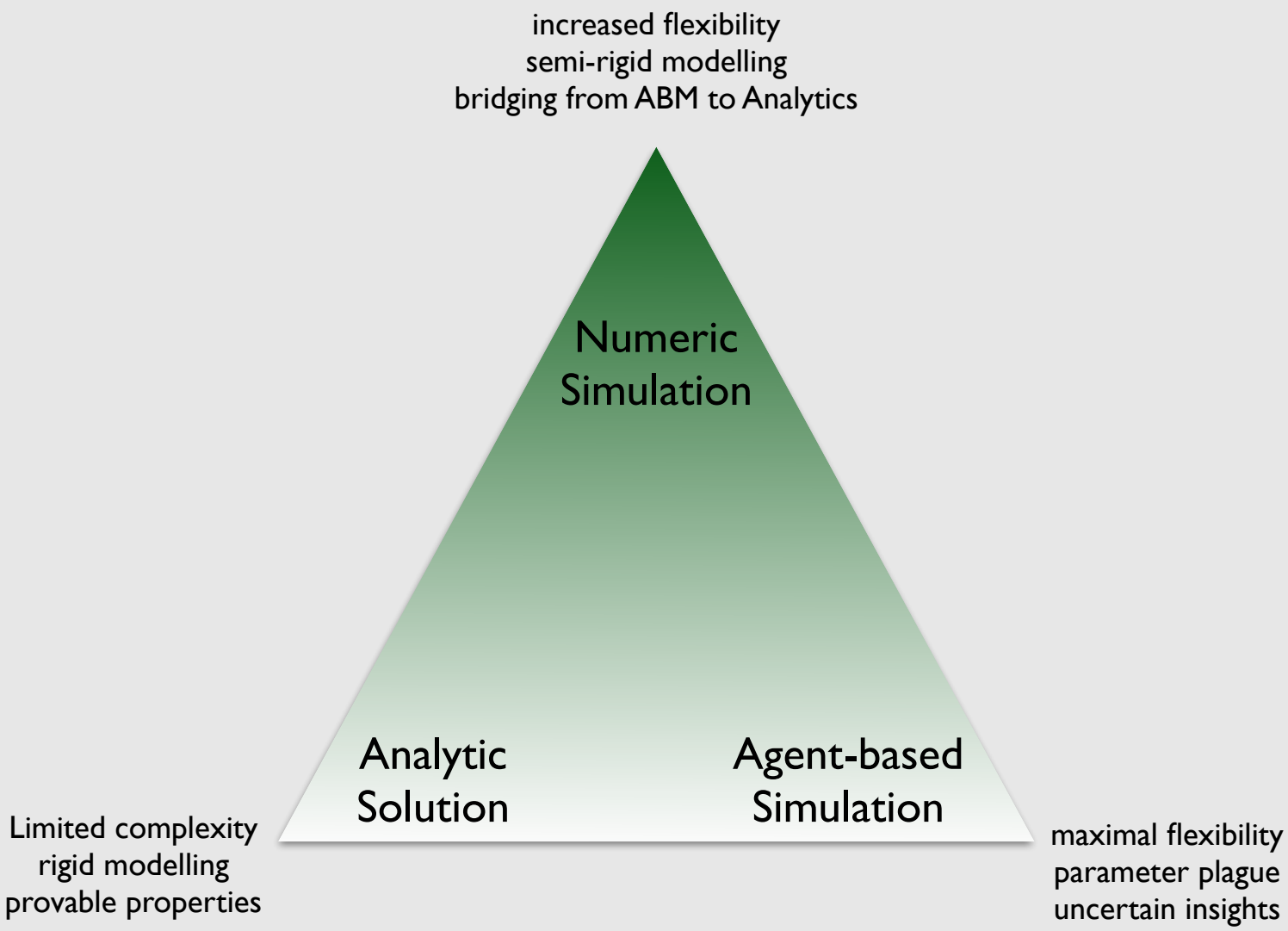
Thomas Schelling (14/4/1921 -),
American Economist,
Nobel Price in Economy 2005

Rules: Schelling Segregation Model

- Two types of ‘residents’ (red/blue).
- residents move if they are unhappy in their environment
- resident prefer an environment of their own color or somewhat mixed
- they turn unhappy if the proportion of agents with a color different from their own exceeds a certain threshold
- Even when residents prefer mixed environments, full segregation occurs



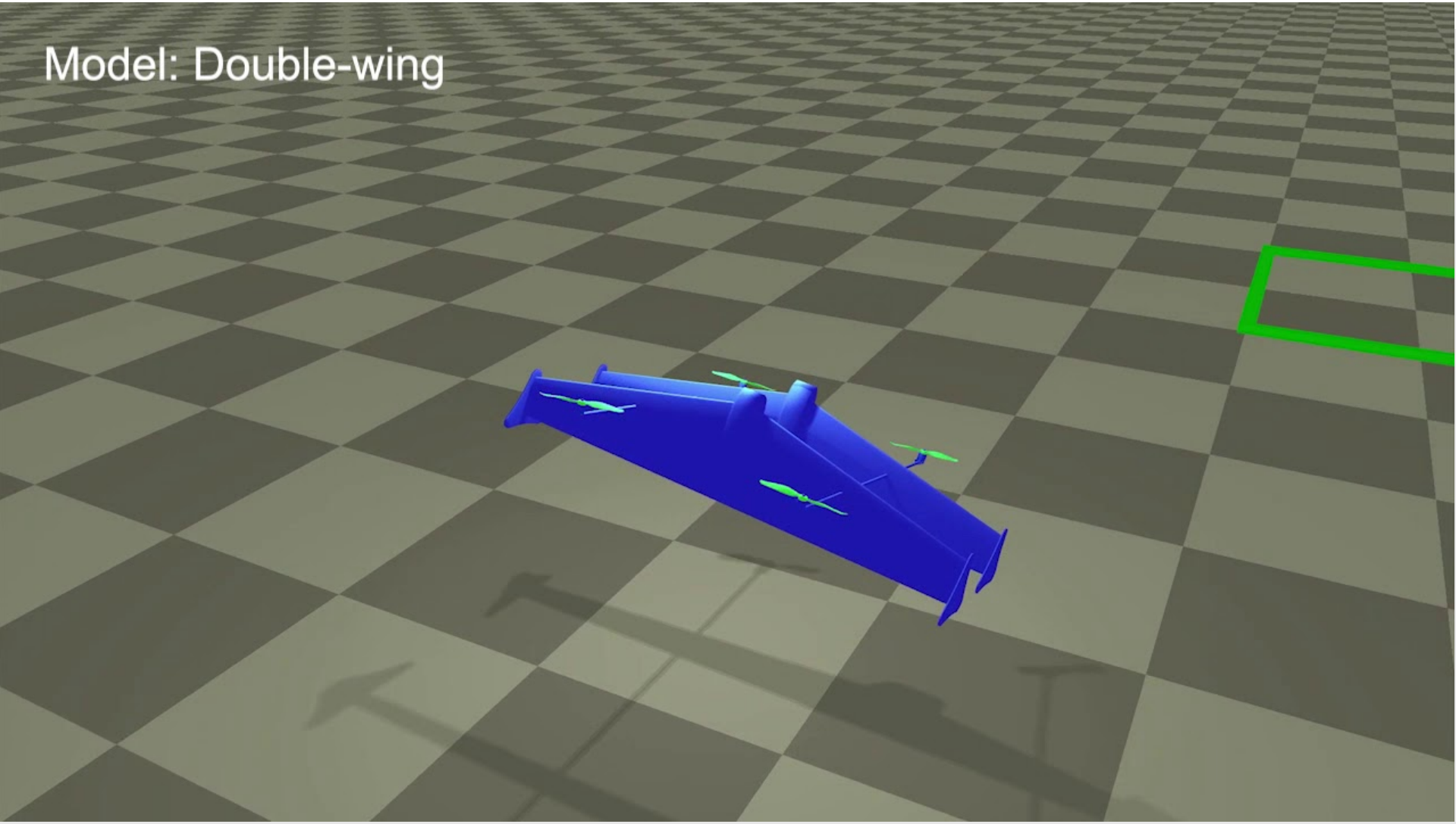
Modelling Approaches



Learning Agents

Learning to act (**single** agents)

Single-agent Reinforcement Learning



1’25” to 2’15”

https://youtu.be/oOuOxgJzsgI

Single-agent Reinforcement Learning

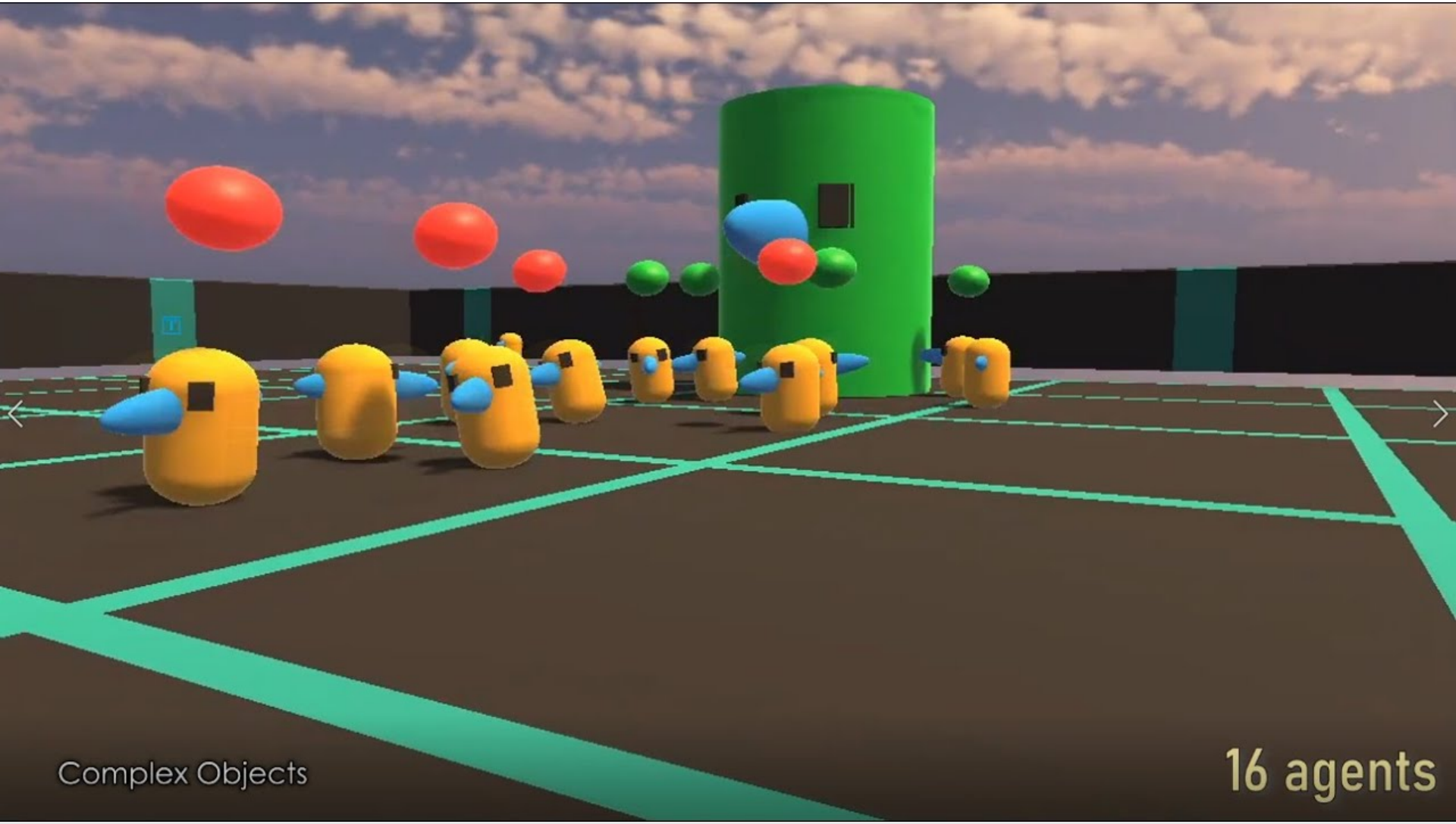
1'50" to 3'00"

https://youtu.be/T0A9voXzhng

Single-agent Reinforcement Learning

From single to **Multi-agent** RL

Multi-agent Reinforcement Learning



2’42”; 3’30”-3’40”; 6’55” to 7’30”

https://www.youtube.com/watch?v=Gv-8X6tNPNw&t=5s

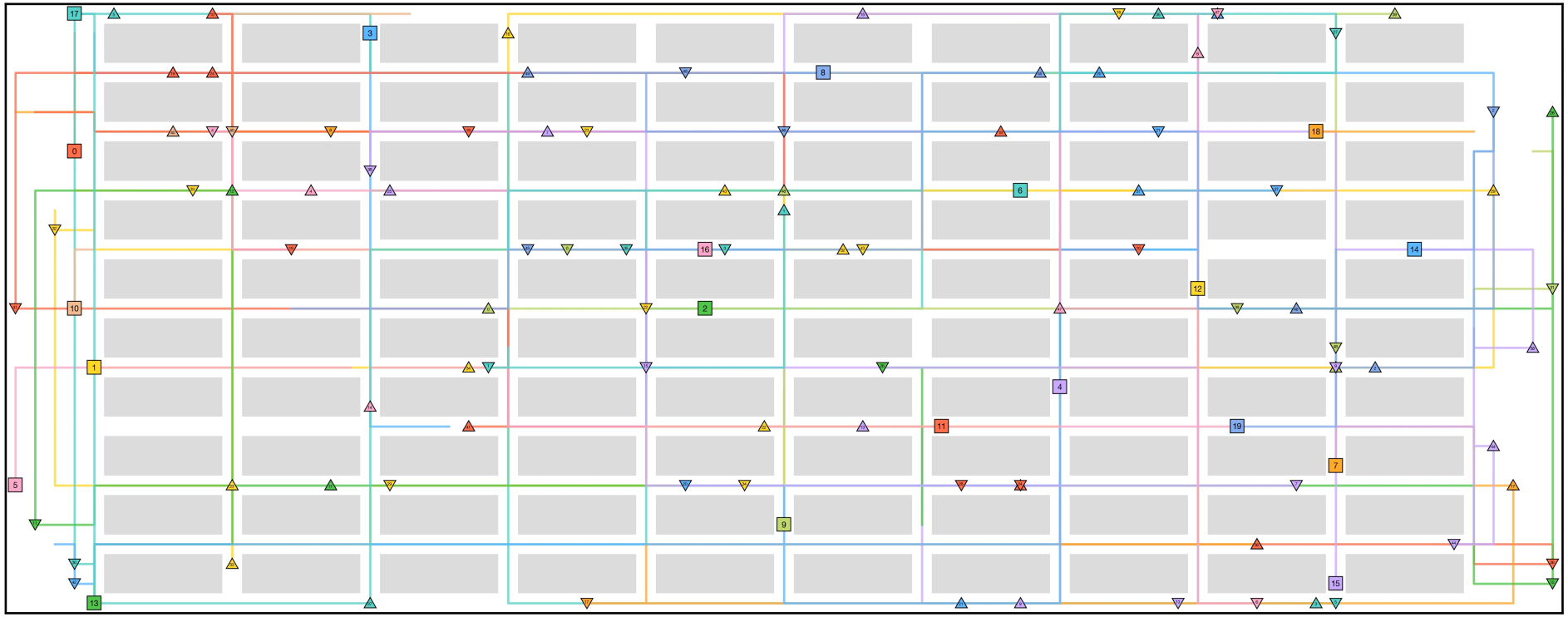
Routing Warehouse Robots

Hercules robots being tested at Amazon's BOS27 Robotics Innovation Hub in Westborough, Massachusetts.

Routing Warehouse Robots

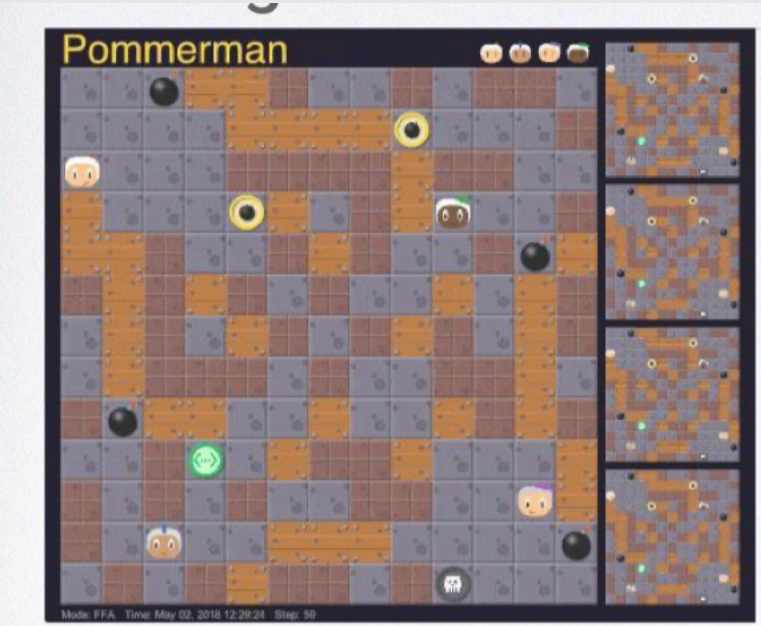
Branch-and-cut-and-price for multi-agent pickup and delivery
Edward Lam <edward.lam@monash.edu>

Time 0.0

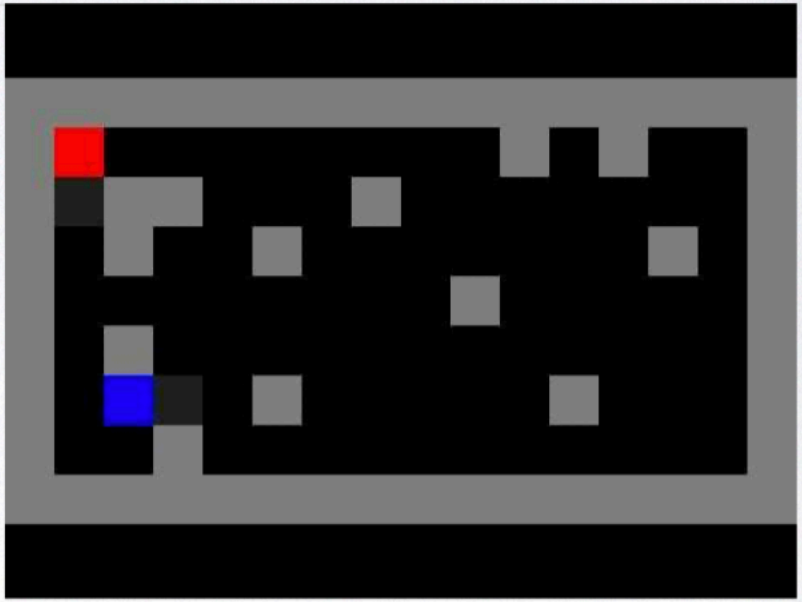


https://ed-lam.com/videos/bcpmapd2024_warehouse.mp4

Multi-agent Reinforcement Learning



pommerman.com



Laser Tag

Typical experimental environments: Grid Worlds

DeepMind says reinforcement learning is 'enough' to reach general AI

E.O. Wilson

The unknown and prodigious are drugs to the scientific imagination, stirring insatiable hunger with a single taste.

In our hearts we hope we will never discover everything.

from: "The diversity of live"

Main Approaches to Investigating MAS

- **Agent-based simulations**
- **Physics-based methods (eg. ODEs, Fokker-Planck)**
- **Reinforcement Learning**
  - **initially for *individual* learning**
- **Game Theory**
  - **mostly concerned with outcomes of multi-agent interactions only, not with learning**
- **Evolutionary Game Theory**
  - **mostly concerned with evolutionary selection and *social* learning**
- **Auction Theory (Resource allocation)**
- **Voting Theory (Social Choice)**

Part 1 (Weeks 1-10): The Game Plan

- **Overview** [today]
- **Analysing complex interactions, no learning**
  System Dynamics, Markov Chains
- **Learning**
  …from the agent perspective, *individual* learning
  - Reinforcement Learning (incl. Deep RL)
  Outcomes, Solution Concepts (“desirable” target states)
  - Game Theory, Nash Equilibrium
  …from the population perspective, *social* learning
  - Evolutionary Game Theory
- **Combining Game Theory and Reinforcement Learning**

Week-to-week structure (tentative)

	1	Introduction & Scoping	
	2	Macroscopic/mesoscopic system dynamics (deterministic & stochastic)	
Learning	3	RL Intro and MDPs	Bellman Equations
Learning	4	Policy and Value Iteration	SARSA, Q-Learning
Learning / Multi-agent	5	Deep Q-Learning	
Multi-agent	6	Game Theory Intro	
Multi-agent	7	Solution Concepts; Nash	MiniMax-Q, Markov Games
Multi-agent	8	Population Games	Evolutionary Game Theory
Multi-agent	9	Social Dilemmas	
Multi-agent	10	Coalition Game Theory	
Multi-agent	11	Auctions	
Multi-agent	12	Voting	

Assessment

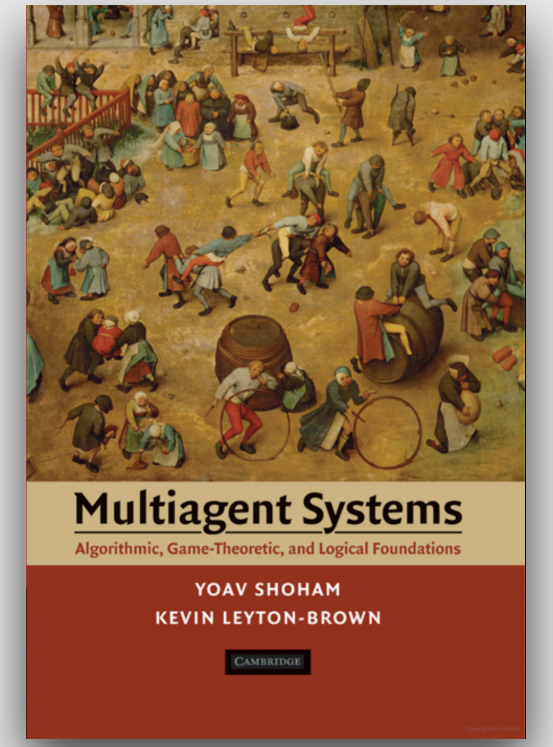
Assessment	Topic	Release	Due	Weight	Assessment mode
not assessed; prep work	Project Stage 1 (single agent learning)				collaborative work
in-semester	Project & Report (collaborative multi-agent task)		May 5	50%	Individual
Exam				50%	

Literature (prescribed)

- ***Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*** **by Kevin Leyton-Brown and Yoav Shoham, Cambridge University Press, 2009.**

- **required (but maybe no need to buy) available via Monash Library**
  - **hardcopy, electronically**
  - **see reading list on Moodle**

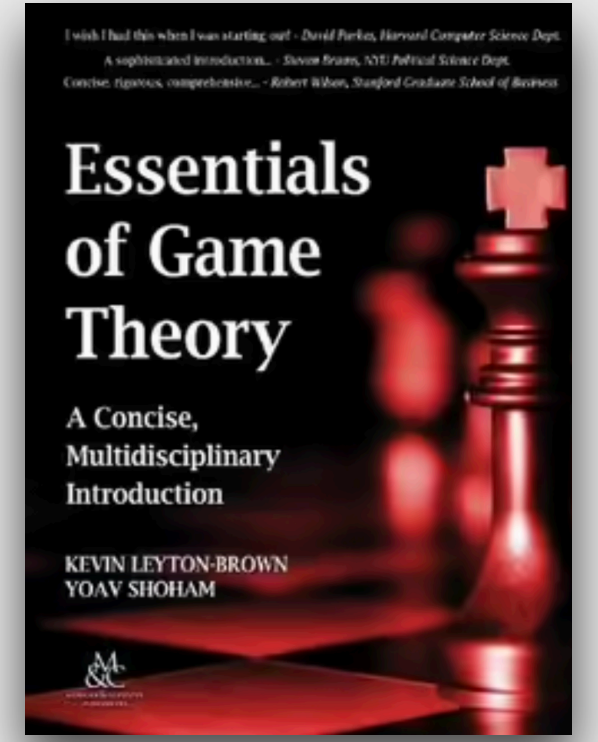
- **available online for free at (if you can't afford to buy it) http://www.masfoundations.org/**



Literature (optional)

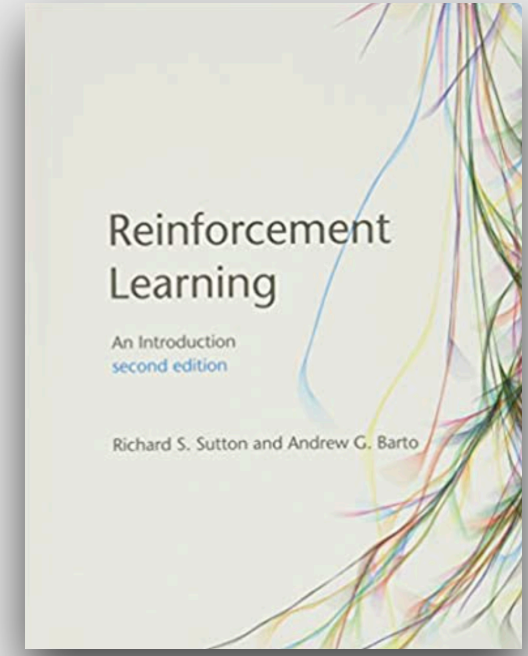
- ***Essentials of Game Theory*** **by Kevin Leyton-Brown and Yoav Shoham, Cambridge University Press, 2009.**

- **abbreviated version of the prescribed text, restricted to game theory**
- **available online https://www.gtessentials.org/**
- **available via Monash Library**
  - **electronically: https://www-morganclaypool-com.ap1.proxy.openathens.net/doi/abs/10.2200/S00108ED1V01Y200802AIM003**



Literature (optional)

- ***Reinforcement Learning: An Introduction*** **(2nd ed) by Richard S. Sutton and Andrew C. Barto**
  MIT Press, 2018.
- **Chapters 1, 3-6**

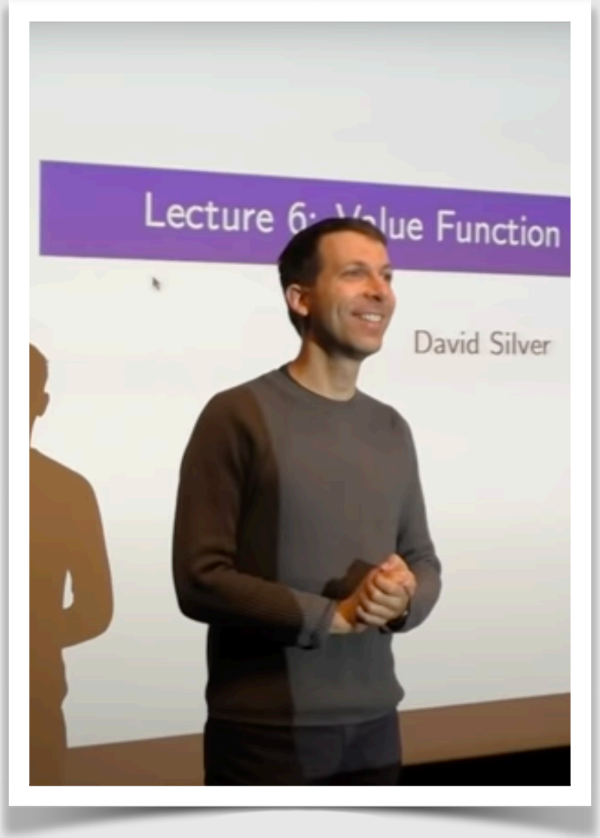


- **available via Monash Library**
  - **hardcopy, electronically**
  - **see reading list on Moodle**

- **available online for free from R. Sutton (if you can't afford to buy it)**
  - **http://incompleteideas.net/**

Youtube Lectures: Reinforcement Learning

- **David Silver's (Deep Mind) recordings of lectures given at UCL**
- **Lectures 1-5**
- **https://www.youtube.com/playlist?list=PLzuuYNsE1EZAXYR4FJ75jcJseBmo4KQ9-**



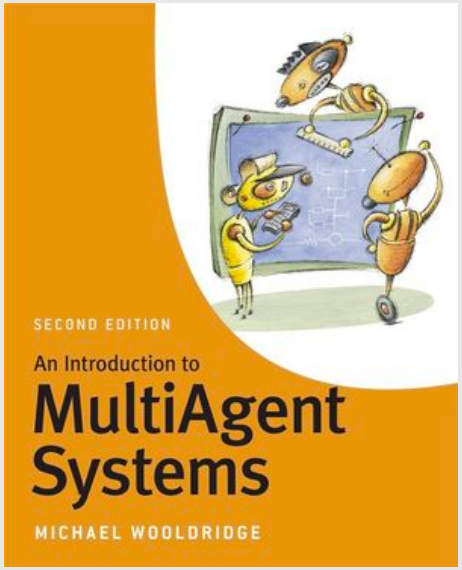
- **other selected literature will be provided**

Literature (optional)

- ***An Introduction*** **to MultiAgent Systems (2nd ed) by Michael Woolridge Wiley, 2009.**

- **available via Monash Library**
  - **hardcopy, electronically**
  - **see reading list on Moodle**

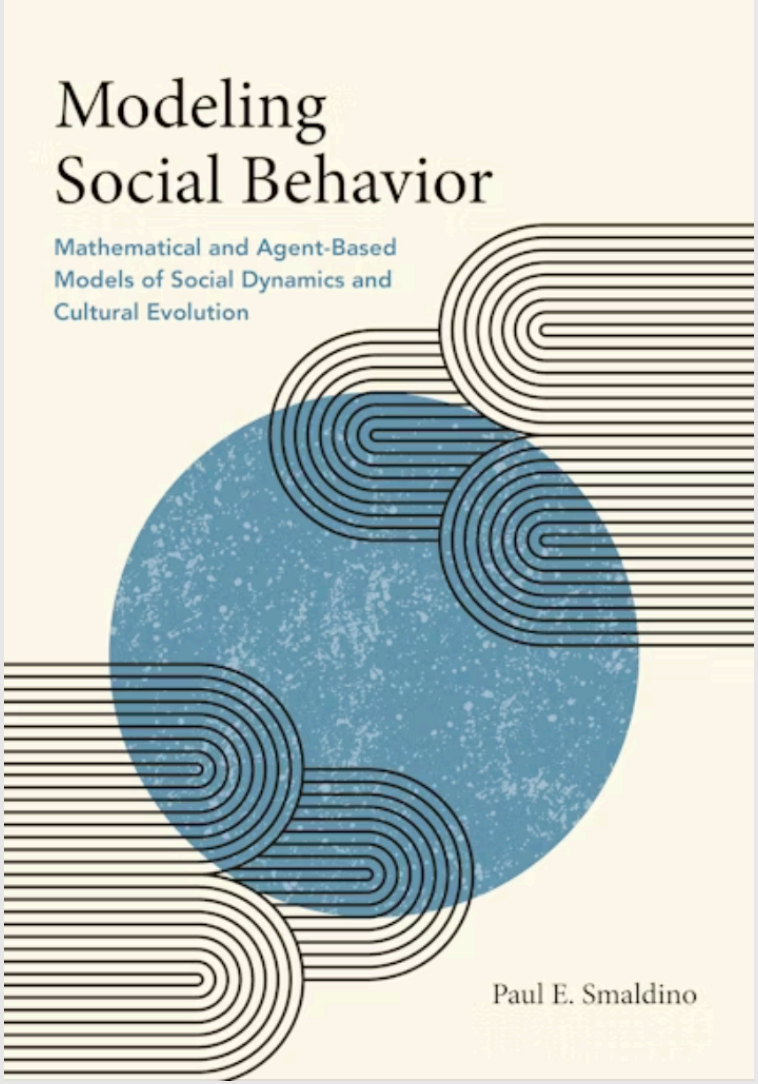
  - **no legal (!) free copies (AFAIK)**



Literature (optional)

- ***Modeling Social Behavior* by**
  Paul E. Smaldino
  Princeton University Press, 2014.

- **available via Monash Library**
  - **hardcopy only**
  - **see reading list on Moodle**

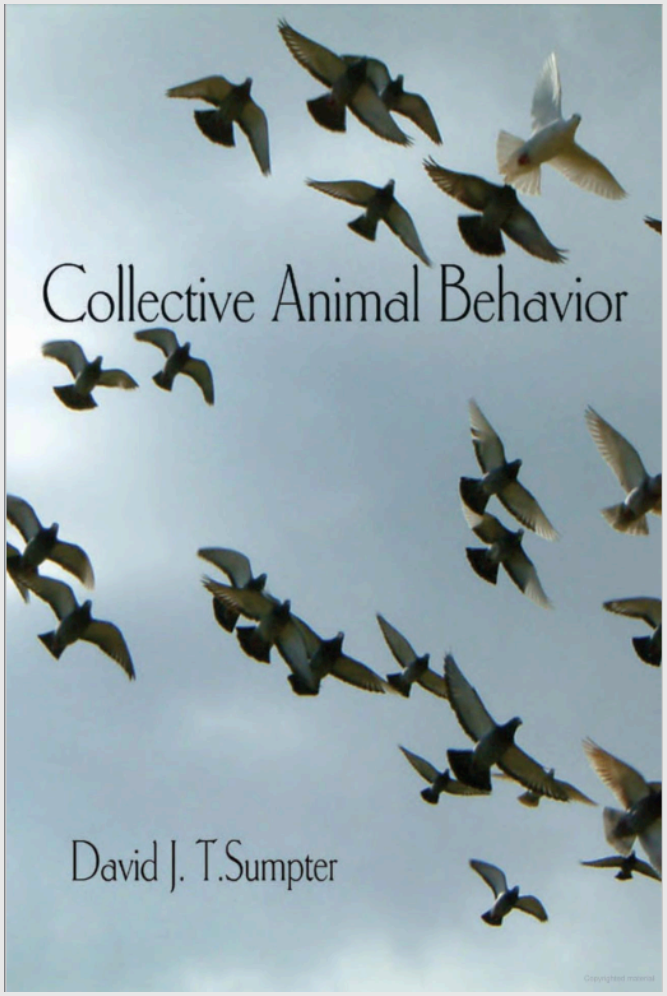


Literature (optional)

- ***Collective Animal Behavior* by**
  David Sumpter
  Princeton University Press, 2010.

- **available via Monash Library**
  - **hardcopy, electronically**
  - **see reading list on Moodle**

  - **no legal (!) free copies (AFAIK)**

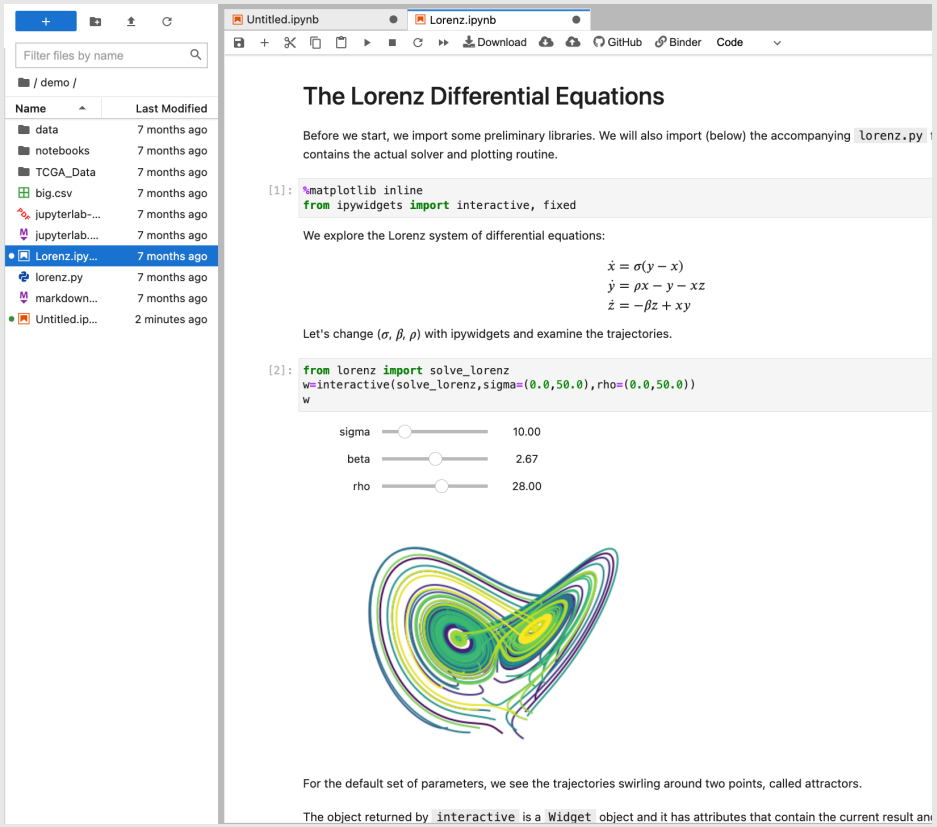


Correspondences for Core Topics

	SLB	Silver	Woolridge
RL	7.4.1-7.4.3; Appendix C	Lectures 1-5	
Non-cooperative GT	3.1-3.3; 3.4.1; 4.1; 4.5.1	n/a	
EGT	6.4; 7.1; 7.7	n/a	
Coalition GT	12.1-12.3	n/a	13
Auctions	11	n/a	14
Voting	9.1-9.4	n/a	12

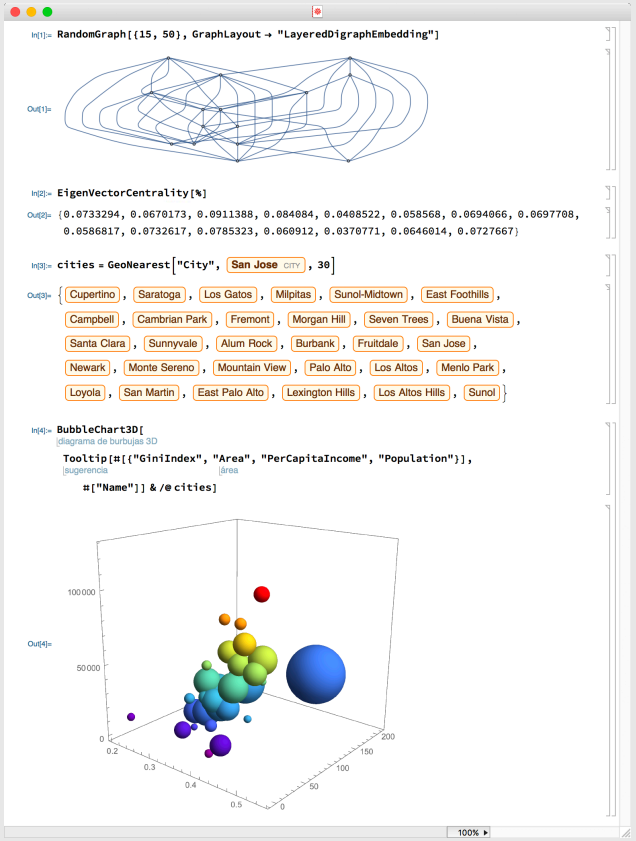
Tools of the Trade

Jupyter Notebooks (Python)



Programming Environment
with comprehensive scientific computing libraries
https://anaconda.org/
https://colab.google/

Wolfram Mathematica



Scientific Computing Environment
fully programmable
symbolic maths