From Micro-Behaviors to Macro-Phenomena

An Introduction to Agent-Based Modeling

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Tutorial team

This tutorial was developed and delivered at EASSS 2026 by Sz-Ting (Christine) Tzeng, with contribution from Bertilla Fabris to the hands-on assignment session.

The slides available on this website are a revised version prepared by Christine Tzeng. They include theory-focused content and a hands-on modeling session, but do not include the hands-on assignment materials.



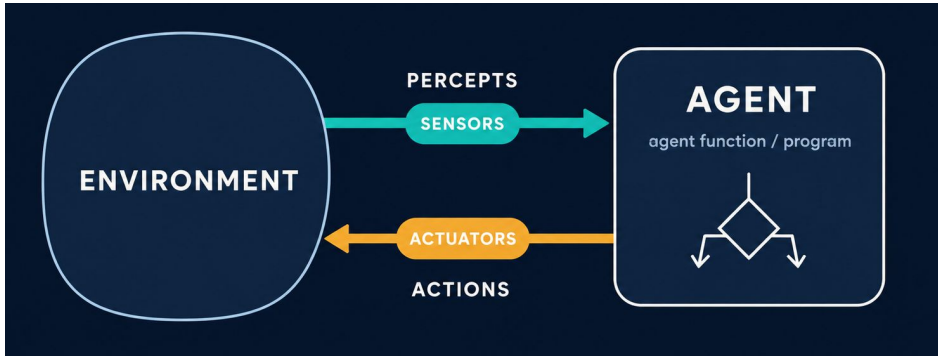
Sz-Ting (Christine) Tzeng
Focus: multi-agent systems, human-centered AI, and value alignment

Learning Goals

- **Explain** the core components of an agent-based model: agents, environments, states, rules, interactions, and emergent outcomes
- **Explore** and **analyze** foundational ABMs in NetLogo by changing parameters, observing, and interpreting system dynamics
- **Connect** local behavior, heterogeneity, and interaction to macro-level social patterns
- **Assess** how alternative rules or interventions affect simulated outcomes, and recognize the limits of policy inference
- **Design** an ABM for a real-world problem, including agents, states, interaction rules, outcomes, and possible interventions

Foundations of Agent-Based Modeling

What is An Agent?



Russell, S. J., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.

“Agent” Disclaimer

ABM agent ≠ LLM-based agent

ABM AGENT
A model component

Person / household / wolf
Patient / hospital
Vehicle / pedestrian

Goal: Represent interactions and examine system outcomes

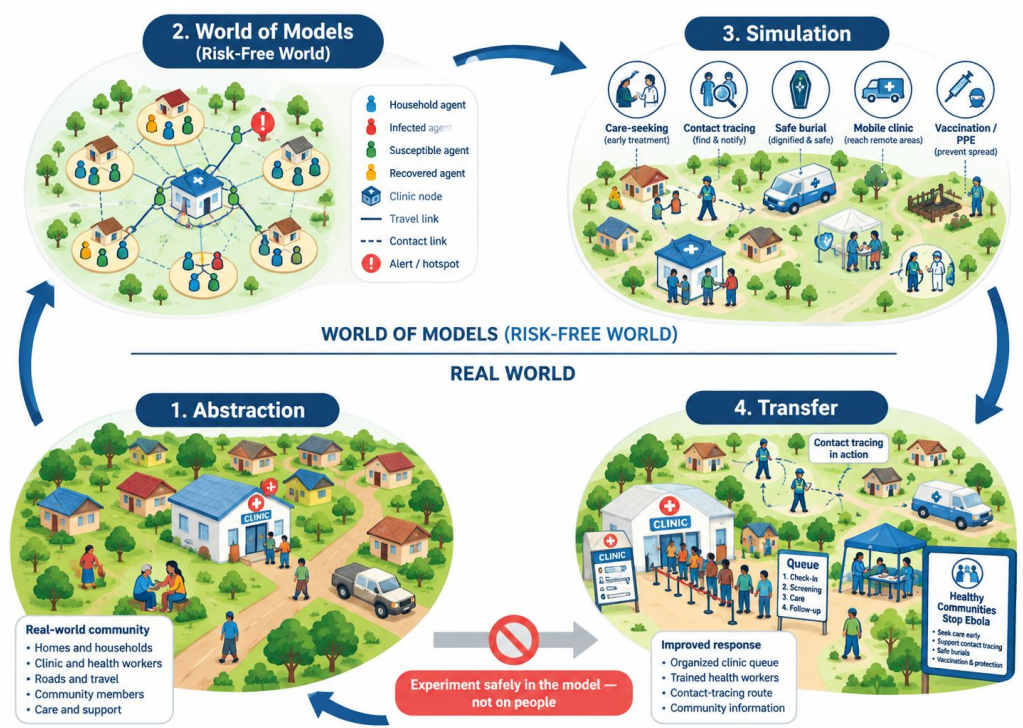
LLM-BASED AGENT
An AI system architecture

LLM + memory + tools
Planning / API calls
Task completion

Goal: perform or assist with tasks in an environment

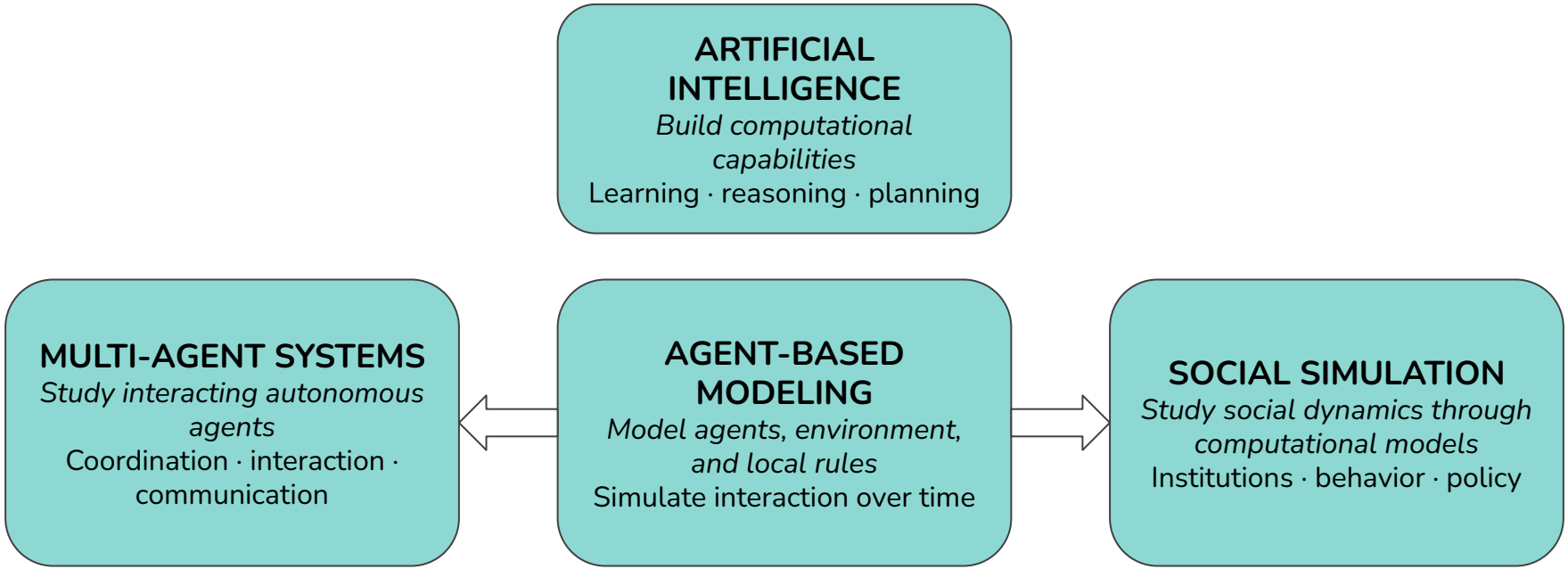
A Model Is a Purposeful Abstraction

- Prediction
- Explanation
- Description
- Exploration
- Illustration
- Analogy
- Social learning
- Optimization



Edmonds et al. (2019) JASSS, *Different Modelling Purposes*

Where Does ABM Sit? AI, MAS, and Social Simulation



Micro-behaviors → Macro-phenomena

Segregation · epidemic trajectories · market dynamics

What Makes A System Complex?

- **Heterogeneity**: Actors differ in state, resources, beliefs, or decision rules
- Local **interaction**: Agents respond to other agents and information within their interaction neighborhood
- **Feedback**: Effects loop back and alter later behavior
- **Adaptation**: Behavior changes as conditions change
- **Nonlinearity**: Small changes can produce disproportionate outcomes
- ...

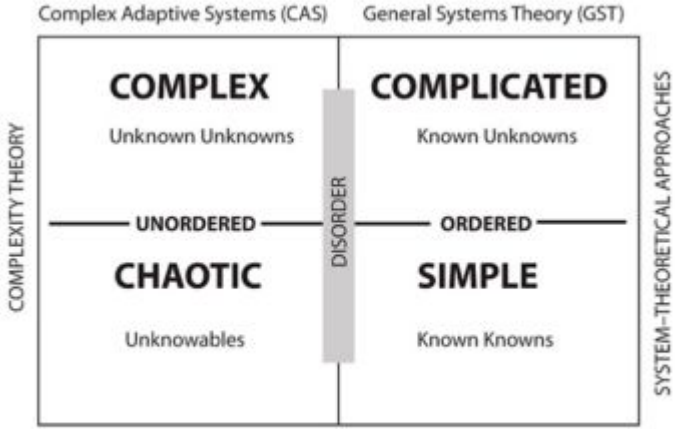


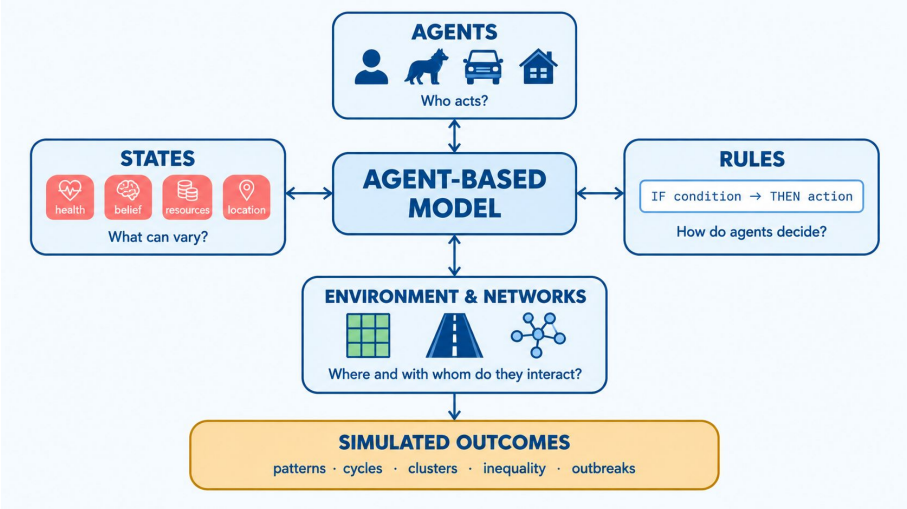
Figure 4. Complexity theory and sensemaking.

Turner, J. R., & Baker, R. M. (2019). Complexity Theory: An Overview with Potential Applications for the Social Sciences. *Systems*, *7*(1), 4. https://doi.org/10.3390/systems7010004

What is ABM

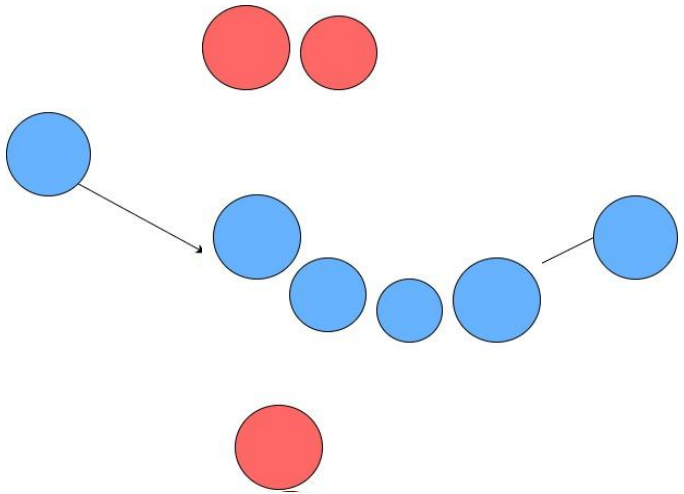
Agent-Based Modeling Makes Mechanisms Explicit

ABM simulates heterogeneous autonomous entities and their interactions to explore how collective patterns and dynamics emerge



Emergence: From Micro-Behaviors to Macro-Phenomena

How can simple local choices produce collective patterns?



Agents converge, and adapt locally

Why Use ABM Instead of Only Averages or Population-Level Variables?

Do individual differences matter?
Model agents with different resources, beliefs, health states, or preferences.

Do local interactions matter?
Represent contagion, social influence, neighborhood effects, and network structure.

Does feedback change behavior?
Observe adaptation, path dependence, tipping points, and non-linear effects.

Can a policy alter local rules?
Compare interventions such as early versus late quarantine.

Advanced ABM

Hidden States

Behavior Is Visible. Its Drivers May Not Be

Visible Layer

- ❏ Moves to another location
- ❏ Avoids contact
- ❏ Accepts vaccination
- ❏ Shares or withholds information

Observable action

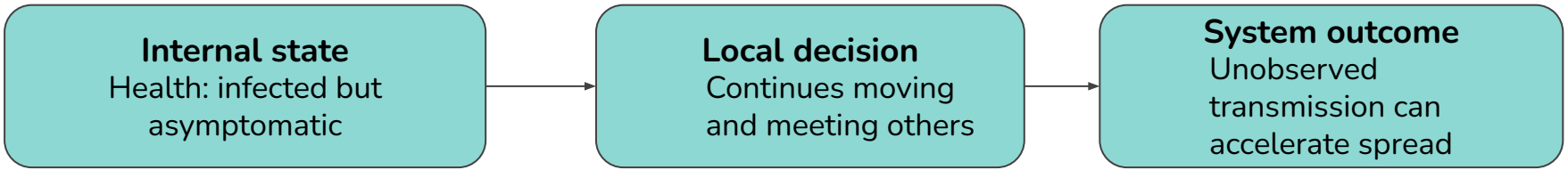
Internal Layer

- ❏ Health status
- ❏ Belief / risk perception
- ❏ Preference
- ❏ Resource constraint

Internal state— not directly observable by other agents

ABM can model a distinction between what agents **do**, what agents **know**, and what observers can **see**.

Hidden States Change Collective Dynamics



Examples:

- Belief → chooses whether to comply → intervention outcome
- Preference → choices of contacts or location → clustering or segregation

Policy Becomes a Mechanism In ABM



Before intervention
Infected agent moves and contacts nearby agents

Policy mechanism
Reduce or remove mobility / contact after becoming infected

After intervention
Fewer contact opportunities

The policy effect comes from the modeled mechanism

Practical Exercise

Policy Exploration

Who receives protection?

When does the response begin?

	Early intervention	Late intervention
Random vaccination	Condition A	Condition B
Targeted vaccination	Condition C	Condition D

Record these outcomes for discussion:

- ❏ Peak number infected
- ❏ Time to peak
- ❏ Total infections
- ❏ Number or duration of restricted agents
- ❏ Assumptions and random seed / repeated runs

Collaborative Design Canvas

Sample problems:

Outbreaks Virus on a Network	Misinformation Rumor Mill	Residential Clustering Segregation / Schelling	Resource Distributions Simple Economy
When does a local outbreak require targeted protection?	How does misinformation spread, and which response slows it?	Can preference changes reduce residential clustering?	What produces unequal resource distributions?

Collaborative Design Canvas

Bring your own problem

- Problem
- Agents
- State variables
- Decision rules
- Interactions
- Outcomes
- Candidate intervention

Get In Touch

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