Agent-based M&S
Outline

• What is agent-based simulation
• What is an agent
• The agent-based M&S tutorial (from Charles M. Macal and Michael J. North)
Agent-based Model

- An **Agent-Based Model** (ABM) is a computational model for simulating the actions and interactions of autonomous individuals in a network, with a view to assessing their effects on the system as a whole.
- It combines elements of game theory, complex systems, emergence, computational sociology, multi agent systems, and evolutionary programming.
- The models simulate the simultaneous operations of multiple agents, in an attempt to re-create and predict the actions of complex phenomena. The process is one of emergence from the lower (micro) level of systems to a higher (macro) level.
- The individual agents are presumed to be acting in what they perceive as their own interests, such as reproduction, economic benefit, or social status, and their knowledge is limited. ABM agents may experience "learning", adaptation, and reproduction.

http://en.wikipedia.org/wiki/Multi-agent_systems
Crowd Behavior Simulation
Emergent Behavior

• An **emergent behavior** or **emergent property** can appear when a number of simple entities (agents) operate in an environment, forming more complex behaviours as a collective.

• An example: the boids
  - [https://www.youtube.com/watch?v=QbUPfMXXQIY](https://www.youtube.com/watch?v=QbUPfMXXQIY)
  - [https://www.youtube.com/watch?v=GUkjC-69vaw](https://www.youtube.com/watch?v=GUkjC-69vaw)
Advantages of ABS (for social simulation)

• An advantage of using computer simulation is that it is necessary to think through one’s basic assumptions very clearly in order to create a useful simulation model.
  – Every relationship to be modeled has to be specified exactly. Every parameter has to be given a value.
  – Disadvantages: simulations of complex social processes involve the estimation of many parameters, and adequate data for making the estimates can be difficult to come by.

• In some circumstances, it can give insights into the 'emergence' of macro level phenomena from micro level actions.

Nigel Gilbert, Agent-Based Social Simulation: Dealing with Complexity, centre for Research on Social Simulation, University of Surrey, Guildford, UK, 18 December 2004
Some Dimensions to differentiate Agent-based models

• **Abstract** (such as studying norms and social inequality) **vs.** **Descriptive** (such as crowd behavior in emergency evacuation)

• **Artificial** (engineered systems) **vs.** **Realistic** (real society)

• **Positive** (analyzing a social phenomenon) **vs.** **Normative** (policy recommendation)

• **Spatial** vs. **Network**

• **Complex** vs. **Simple** (production system by action rules)

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Agent-Based Simulation

- Some of the simulated entities are *agents*
- Explicitly represents specific behaviors of specific individuals – contrast with traditional macro-level aggregated representations
- Facilitates simulation of group behavior in highly dynamic situations. Allows study of "emergent behavior"
- Well-suited to populations of heterogeneous individuals
  - vehicles (and pedestrians) in traffic situations
  - actors in financial markets
  - consumer behavior
  - humans and machines in battle fields
  - people in crowds
  - animals and/or plants in eco-systems
  - artificial creatures in computer games
  - enzymes, DNA, and mRNA in a bio cell
What Is an “Agent?”

• An agent is…
  – An individual with a set of characteristics or attributes
  – A set of rules governing agent behaviors or “decision-making” capability, protocols for communication
  • Respond to the environment
  • Interact with other agents in the system

• Agents are diverse and heterogeneous
  – This makes it interesting!
Spectrum of Agent Properties

- belief management capability
- language skills
- communication capabilities
- manipulation skills
- intention management capability
- mobility skills
- navigation skills
- goal management capability
- domain knowledge
- perception abilities
- decision making abilities
- agent model
- domains...

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The Schelling Model Is a Simple Agent-based Simulation

- Randomly seed blue and red agents across the square
- Apply “agent movement rules” repeatedly for all agents

**Agent Movement Rules in Schelling Model:**

1. Agent computes fraction of neighbors who are its own color
2. If number greater than preference, agent is satisfied – don’t move
3. Else, agent looks for nearest unoccupied site that satisfies its preference and moves there

Results for Preference Factor set to 25%, that is, if 25% (or more) of an agent’s immediate neighbors are of the same color, the agent is happy and decides to stay put.

Charles M. Macal, Introduction to Modeling, April 3-5, 2006
The Schelling Model Is a Simple Agent-based Simulation

• The model shows that if Preference factor is set as low as 25%, segregation patterns result, as shown in the figure.
• Since Schelling’s seminal work, the basic cellular automata approach has been used to model everything from…
  • settlement patterns to international conflict
  • financial markets to environmental impacts
  • status symbols and fads to the adoption of social norms and conformity
Other Examples

• http://ccl.northwestern.edu/netlogo/models/ – Ant model

• http://www.massivesoftware.com/
A “Structured” View of a ABM

Inter-agent communication, social network

Agent → Environment → Agent → Environment → Agent
A Formal Definition of An Agent

- Ferber considers an agent in interaction with the world as a system composed of dynamic coupled two subsystems, the coupling taking place through perceptions that the agent has for world and actions that modify this world. He represents a mono agent system by the couple \( < a, w > \) where \( a \) is an agent and \( w \) is a world, those are described in (1).

\[
\begin{align*}
a &=< P_a, \text{Percept}_a, F_a, \text{Infl}_a, S_a > \\
w &=< E, \Gamma, \Sigma, R >
\end{align*}
\]

(1)

- Where, - \( P_a \) represents the function of perception of the agent,
- \( \text{Percept}_a \) the set of stimuli and sensations that an agent can receive,
- \( F_a \) the function of behavior of the agent that determines the agent’s state from its perceptions and the previous state,
- \( \text{Infl}_a \) the function of action of the agent, that means the function that has the tendency to modify the evolution of the world while producing influences [7],
- \( S_a \) the set of the agent’s internal states,
- \( E \) the space in which the agent evolves,
- \( \Gamma \) the space of influences produced by the agent and having like consequences to modify the evolution of the world,
- \( \Sigma \) the set of states of the world
- \( R \) the law of evolution of the world (Eq. (2)).

\[
\begin{align*}
P_a : \Sigma \rightarrow \text{Percept}_a \\
\text{Infl}_a : S_a \rightarrow \Gamma \\
F_a : S_a \times \text{Percept}_a \rightarrow S_a \\
R : \Sigma \times \Gamma \rightarrow \Sigma
\end{align*}
\]

(2)

- Those functions satisfy equations (3) that describe the agent’s dynamics in interaction with its environment.

\[
\begin{align*}
s_a(t + 1) &= F_a(s_a(t), P_a(\sigma(t))) \\
\sigma(t + 1) &= R(\sigma(t), \text{Infl}_a(s_a(t)))
\end{align*}
\]

(3)

- Where, \( s_a \) is an element of \( S_a \) and \( \sigma \) is an element of \( \Sigma \).
How to model an agent: Agent Architecture

• Simple agent
  – if-then rules. Example: game of life
  – FSM

• Behavior-based agents
  – Subsumption
  – Maes’ spreading activation network
  – Motor Schema

• Multi-Layer architecture

• BDI (Belief – Desire – Intention)

• Cognitive Architecture: Soar, ACT-R
When to use ABM?

- Emergence: simple rules $\rightarrow$ complex behavior
- "Locality" : no global knowledge; agents interact with their "local" neighbors only
- Spatial system
- Social network
- Heterogeneity is important
- The system is constructed by “individual agents” by nature

When to use Discrete Event Simulation Model?
More Details about the Crowd Behavior Simulation Model

http://grid.cs.gsu.edu/xhu/papers/crowdSimulation_submission.pdf

BehaviorSim: A Learning Environment for Behavior-based Agent
https://grid.cs.gsu.edu/xhu/papers/SAB08_submit.pdf#page=1
1. Agent-based M&S Tutorial
2. Agent Based Modeling: Population Health from the Bottom Up

2007 Symposia Series on Systems Science and Health
http://obssr.od.nih.gov/news_and_events/lectures_and_seminars/systems_symposia_series/system_symposium_three/systems_symposium_three.aspx

Discussion

• What is the relationship between cellular space M&S and agent-based M&S?

• What is the relationship between discrete event M&S and agent-based M&S?
HW3

1. Anything related to your own research (if the complexity is enough, two students can work together as a group).

2. Any “interesting” problem that you are interested in modeling and studying.

3. Implement the standard diamond interchange and/or the diverging diamond interchange model.

4. Combined behaviors and groups on page http://www.red3d.com/cwr/steer/. Note: if you choose Leader Following steering behavior, you need to implement both modes.

- Case 1 and case 2 are encouraged. However, for these two cases you need to communicate with the instructor to get an approval first.
- For case 1, you can choose to use JAVA or DEVSJAVA instead of Netlogo. But it has to be agent-based simulation.
- For the case 2, your idea has to be “novel” and “interesting”, e.g., it is not related to or adapted from the existing models in Netlogo’s model library. By default, my answer to your case 2 proposal would be “No”. I need strong reasons to be convinced otherwise.
- If you choose Case 4, your final project cannot be based on HW3.

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