An Introduction to Agent-Based Modeling

Unit 5: Components of an Agent-Based Model

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So What Makes Up An ABM?

Agents

Environment

Interaction
Basic Agent Properties

WHO
COLOR
HEADING
XCOR and YCOR
SHAPE
LABEL
LABEL-COLOR
BREED
HIDDEN?
SIZE
PEN-SIZE
PEN-MODE
Author-Defined Properties

• In Traffic Basic
  • speed-limit
  • speed
  • speed-min

• Types of values
  • Fixed (10)
  • Distributions (random-normal 10 1)
  • Variable (acceleration)
Agent Actions

Standard Actions
- FORWARD
- RIGHT
- LEFT
- HATCH
- DIE
- MOVE-TO

User-Defined Actions
- speed-up-car
- slow-down-car
Collections of Agents

- Built-In Collections
  - *patches, turtles, links*
  - *turtles-here, in-link-neighbors*
- Agent Breeds
  - *influentials, imitators*
  - can have their own properties
- Agentsets
  - *with*
  - *turtles-on*
Agentsets and Lists

• Lists can hold any type of item, but agentsets can only hold agents
• *no-turtles*
• We can convert from one to the other, primarily using ?
  
  foreach a-list [
    ask ? [ do something ]
  ]
Agentsets and Computation

• It is important to realize that when an agentset is created it remains static until it is created again or updated
• Agentset Ordering
• Agentset Efficiency
The Level of an Agent

Tumor Model

AIDS Model
Meta-Agent

• An agent composed of other agents
• Turtles all the way down!
• *tie* (for a spatial example)

Proto-Agent

• An agent that is not fully realized
• Often built as regular agents
Agent Cognition

• *Agent cognition* is the process by which agents examine their own properties and the world around them, and then make a decision about what actions to take.

• Before constructing your model, you should consider what level of cognition the agents will have?

• The more complex the cognition, the more computational effort may be required, but potentially the more realistic the model.
Types of Agent Cognition
(Russell and Norvig, 1995)

- Reflexive
- Utility-Based
- Goal-Based
- Adaptive
Reflexive Agents

- Simple rules where agents react to what is around them
- Often represented by if-then rules
- Car in Traffic Basic
Utility-Based

- Agents are attempting to maximize some utility function
- Often requires agents to try different actions and then observe the outcome on the utility function
- Traffic Basic Utility
Goal-Based

• Agents are attempting to achieve some goal
• As opposed to utility, there is some criteria that establishes when the agent has achieved its goal
• Traffic Grid Goal
Adaptive Agent

- Agents can change not only their decisions but also their strategies
- The action that an agent takes given the same environment may be different over time based on their past experience
- Traffic Basic Adaptive
Environments

• The second main component
• A number of ways to represent
  • patches - the environment is composed of a number of spaces
  • uniform - one large agent with a uniform set of properties
  • external - could be implemented outside of the ABM environment
Four of the Most Popular Types of Environments

• Spatial Environments
• Network-Based Environments
• 3D Worlds
• GIS
Spatial Environments

• Discrete Spaces
  • Lattice Graphs (mesh graphs or grid graphs)
    • Square Lattice

Von Neumann

Moore
Hex Grids

Hex Cells

Hex Turtles
Continuous Space

- NetLogo is a continuous space with a discrete laid on top of it

ask patches with
  [(pxcor + pycor) mod 2 = 1 ]
  [
    set pcolor white
  ]
Boundary Conditions

- **Toroidal Topology**
  - Wrapping
  - Boids Model

- **Bounded Topology**
  - Mazes
  - Ants Model

- **Infinite Plane Topology**
  - Track Agents Anywhere
  - Random Walk 360 model
Network Environments

• Different Types of Networks
  • Grid Environments are Regular Networks
  • Scale-Free / Preferential Attachment
  • Random
  • Small World
  • Real World Data
Visualizations of Networks

Watts and Strogatz, 1997

Preferential Attachment Model
Barabasi and Albert, 1999

Twitter
Stonedahl et al., 2010
Different Types of Measures for Networks

- Degree Distribution
  - How many friends should we expect a person to have?
- Average Clustering Coefficient
  - On average how many friends of my friends are my friends?
  - Out of all possible triangle connections between my friends how many exist?
- Average Path Length
  - How many friendship connections is it from any person in the network to any other person?
- Often real-world networks:
  - have surprisingly low average path lengths for a high clustering coefficient
  - tend to be power-law scaled when it comes to degree distributions
3D Environments

3D Sandpile
GIS Environments

GIS General Examples

projection: WGS_84_Geographic
setup
display-cities
On/Off label-cities
display-rivers
On/Off label-rivers
display-countries
On/Off label-countries
display-rivers-in-patches
display-population-in-patches
display-countries-using-links
draw-us-rivers-in-green
display-elevation
display-gradient-in-patches
display-elevation-in-patches
highlight-large-cities
match-cells-to-patches
clear-drawing
sample-elevation-with-patches
Interactions (the third main element)

• Agent-Self Interactions
  • Agents can interact with themselves
  • Checking to see if a sheep has enough energy to reproduce
• Environment-Self Interactions
  • Patches can interact with their own state variables
  • Regrowing grass within a patch

• Agent-Agent Interactions
  • Agents can interact with other agents
  • Wolves eating sheep

• Environment-Environment Interactions
  • Parts of the environment can interact with each other
  • Spatial Diffusion

• Agent-Environment Interaction
  • The agent can interact with the environment
  • Sheep eating grass
Observer / User Interface

- Design the interface well
- Make sure buttons and sliders are placed where it makes sense to place them
Creating Good Visualizations
Kornhauser et al., 2007

• Simplify the Visualization
  • Remove unwanted clutter
• Explain the Components
  • Make sure it is obvious why each element is there
• Emphasize the main point
  • All models tell a story, make sure the story is obvious
Batch vs. Interactive Interaction

• Interactive
  • Normal way of using NetLogo
  • via immediate use of the Graphical User Interface
• Batch
  • Running many models at once can be done either:
    • via the GUIala BehaviorSpace
    • via the command line via Headless Running
Schedule

• The schedule is a description of the order of events in which the model operates
• SETUP and GO
• Synchronous vs. Asynchronous Updating
  • Asynchronous: Traffic Basic, Wolf Sheep, Ants, Segregation
  • Synchronous: Cellular Automata, Ethnocentrism
• Sequential vs. Parallel Actions
  • Sequential: Agents take actions in turns
  • Parallel: Agents operate simultaneously (Termites)
Unit 5 Overview

- Agents
- Agent sets
- Agent Granularity
- Agent Cognition
- Meta-Agents and Proto-Agents
- Spatial and Network Environments
- 3D and GIS Environments
- Interactions
- Interface
- Schedule
- Unit 5 Slides
- Course Feedback
- Unit 5 Test