Removing Stumbling Blocks: Using UML for Graphically Describing ABMs in OR

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Peer-Olaf Siebers (Nottingham University)

pos@cs.nott.ac.uk
Content

• Introduction to the Ideas of ABM/S
• Difficulties of Using ABM/S in OR/MS
• Solution: The UML Notation (e.g. State Machines)
• Building a UML State Machine: Step-by-Step Guide
• Case Studies
  – Hybrid ABM/DES Model (non synchronised)
  – Pure ABS Model (synchronised)
Introduction to the Ideas of ABM/S
Heroes and Cowards Game [Wilensky and Rand 2013]

• The (very simple) rules

![Diagram showing the game flow for Heroes and Cowards Game]
Heroes and Cowards Game [Wilensky and Rand 2013]
Heroes and Cowards Game  [Wilensky and Rand 2013]

```
to setup
  clear-all
  ask patches [ set color white ] ;; create a blank background
  create-turtles number [ setxy random-xcor random-ycor ]
  ;; set the turtle personalities based on chooser
  if (personalities = "brave") [ set color blue ]
  if (personalities = "cowardly") [ set color red ]
  if (personalities = "mixed") [ set color one-of [ red blue ] ]

  ;; choose friend and enemy targets
  set friend one-of other turtles
  set enemy one-of other turtles
end
reset-ticks

to go
  ask turtles [ if (color = blue) [ act-bravely ]
    if (color = red) [ act-cowardly ]
  ]
tick
end

to act-bravely
  ;; move toward the midpoint of your friend and enemy
  facexy (xcor of friend + xcor of enemy) / 2
  (ycor of friend + ycor of enemy) / 2
  fd 0.1
end

to act-cowardly
  ;; put your friend between you and your enemy
  facexy (xcor of friend + (xcor of enemy) / 2
  (ycor of friend + (ycor of enemy) / 2
  fd 0.1
end

; Copyright 2010 Uri Wilensky.
; See Info tab for full copyright and license.
```
Paradigms and World Views

Process oriented world view
Process based decision making

SD (OR/MS + Business)
Theory driven; equation based

DES (OR/MS)
Data driven; UML based

Traditional DES (OR/MS)

Object Oriented DES (OR/MS)

Object oriented world view
Entity based decision making

ABM/S (Business + Social Science + Economics)
Theory driven; equation based

ABM/S (Social Science)
Data driven; equation based

Multi Agent Systems (Software Engineering)
Data driven; UML based

Agent Oriented DES (ABM + DES) (OR/MS)
Data + theory driven; UML based; non-synchronised

Object Oriented ABM/S (OR/MS)
Data + theory driven; UML based; synchronised

Data driven: Data for model formulation (in Social Sciences can be quantitative and qualitative); data for model validation
Theory driven: Theories for model formulation; data for model validation
Agent-Based Modelling

• In Agent-Based Modelling (ABM), a system is modelled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules.

• ABM is a mindset more than a technology. The ABM mindset consists of describing a system from the perspective of its constituent units. [Bonabeau 2002]

• ABM is well suited to modelling systems with heterogeneous, autonomous and proactive actors, such as human-centred systems.
Agent-Based Modelling

- Borrowing from Artificial Intelligence: From simple to complex
  - Simple reflex agent

Russell and Norvig (2003)
Agent-Based Modelling

• Borrowing from Artificial Intelligence: From simple to complex
  – Learning Robo-Dog (SONY's AIBO)

Russell and Norvig (2003)
Agent-Based Modelling

• What do we mean by "agent"?
  – Agents are **objects with attitude**!

• Properties:
  – Discrete entities
    • With their own goals and behaviours
    • With their own thread of control
    • With their own memory
  – Autonomous decisions
    • Capable to adapt
    • Capable to modify their behaviour
  – Proactive behaviour
    • Actions depending on motivations generated from their internal state
Agent-Based Modelling

- The agents can represent individuals, households, organisations, companies, nations, ... depending on the application.

- ABMs are essentially decentralised; there is no place where global system behaviour (dynamics) would be defined.

- Instead, the individual agents interact to produce complex collective behaviour patterns.
Agent-Based Modelling

• Benefits of ABM
  – ABM provides a natural description of a system
  – ABM captures emergent phenomena

• Emergence
  – Emergent phenomena result from the interactions of individual entities. **The whole is more than the sum of its parts** [Aristotle BC] because of the interactions between the parts.
  – An emergent phenomenon can have properties that are decoupled from the properties of the part (e.g. patterns appearing).
  – Example: Traffic Jam Dynamics
Agent-Based Modelling

• When to use ABM? [Siebers et al. 2010]
  – When the problem has a **natural representation as agents** - when the goal is modelling the behaviours of individuals in a diverse population
  – When agents have relationships with other agents, especially **dynamic relationships** - agent relationships form and dissipate, e.g., structured contact, social networks
  – When it is important that individual agents have **spatial or geo-spatial aspects** to their behaviours (e.g. agents move over a landscape)
  – When it is important that agents **learn or adapt**, or populations adapt
  – When agents engage in **strategic behaviour**, and anticipate other agents' reactions when making their decisions
  – ...

Agent-Based Simulation

- The Sims: Interactive Organisational Agent-Based Simulation
Agent-Based Simulation

• Building an ABS model (OR/MS)
  – Identify active entities (agents)
  – Define their states and behaviour
  – Put them in an environment
  – Establish connections
  – Test the model

• Validating an ABS model
  – System behaviour is an emergent property
  – Validation on a micro level
  – Experimental validation at macro level (if possible)

• Alternative (e.g. Ecology)

Grimm and Railsback (2005)
Agent-Based Simulation

• How "could" an agent based simulator work? [Macal 2013]
  – Loop over time horizon
    • Loop over randomised list of agents. For each agent \textit{A} in list:
      – Execute agent \textit{A} behaviour
      – Update state of agent \textit{A} (based on agent \textit{A}'s state, the states of agents that interact with agent \textit{A}, and the state of the environment).
      – Update other agents states and the environment (if appropriate)
    • End loop over randomized list of agents
  – Increment \( t \) in time loop and repeat until end of simulation time horizon
Difficulties of Using ABM/S in OR/MS
Why is ABM/S still in its Infants in OR/MS?

• Some Stats:

<table>
<thead>
<tr>
<th>term 1</th>
<th>term 2</th>
<th>2006-2009</th>
<th>2010-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>simulation</td>
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<td>1298</td>
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<tr>
<td>agent based</td>
<td>social simulation</td>
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</tr>
</tbody>
</table>

Source: International Abstracts in Operations Research (http://www.palgrave-journals.com/iaor/)
Why is ABM/S still in its Infants in OR/MS?

• What do you think?
Why is ABM/S still in its Infants in OR/MS?

- Why don't we adopt the ABM/S approaches from other disciplines?

<table>
<thead>
<tr>
<th>Operations Research</th>
<th>Business, Economics, Social Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical basis</td>
<td>Theoretical basis</td>
</tr>
<tr>
<td>Improving the real world</td>
<td>Thinking about the real world</td>
</tr>
<tr>
<td>Data collection and analysis</td>
<td>Dynamic hypothesis</td>
</tr>
<tr>
<td>Validation: Sufficient accuracy for purpose</td>
<td>Plausibility: Seeming reasonable or probable</td>
</tr>
<tr>
<td>Implementing findings</td>
<td>Learning + understanding</td>
</tr>
</tbody>
</table>

after Robinson (2010)
Why is ABM/S still in its Infants in OR/MS?

• My hypotheses:
  – It is due to the fact that other disciplines do not use a graphical notation while in OR simulation we are used to a graphical notation
    • If a graphical notation (as in SD and DES) can be established the number of users of ABM will grow rapidly
  – It is due to the fact that it is assumed that huge computer power is required for ABMs
    • If a combined ABM/DES approach is considered as an alternative (which does not require synchronisation) usability of ABM will grow rapidly
    • If the right level of abstraction is chosen (perhaps multiple models at different levels of abstraction need to be build for solving a problem) ABM becomes feasible and the application of ABM will grow rapidly
Hybrid ABM/DES Simulation

Communication layer

Agent layer

DES layer

Direct interactions
Network activities

Let entities interact + communicate

Active entities
Behavioural state charts

Replace passive entities by active ones

Passive entities
Queues
Processes
Resources
Solution: The UML Notation
Unified Modelling Language (UML)
Defining Behaviour Using State Charts

• Typical elements of a state chart diagram
  – States
    • Represents a location of control with a particular set of reactions to conditions and/or events
  • Examples
    – Cup can be in state **full** or **empty**
    – Person can be in state **idle** or **busy**

  – Transitions
    • Movement between states, triggered by a specific event
Defining Behaviour Using State Charts

• Typical elements of a state chart diagram
Simple Agent-Based Simulation Example
Building a Simple State Chart Step-by-Step

- Office workers
Building a Simple State Chart Step-by-Step

- What is the principal difference between these solutions?
Case Study 1
(For more details see Siebers and Aickelin 2011)

Understanding the Impact of Management Practices on Company Performance
Case Study: Context

• Case study sector
  – Retail (department store operations)

• Developing some tools for understanding the impact of management practices on company performance
  – Operational management practices are well researched
  – People management practices are often neglected

• Problem:
  – How can we model proactive customer service behaviour?
Case Study 2
(For more details see Zhang et al 2010)

Office Building Energy Consumption
Case Study: Context

• Office building energy consumption
  – We focus on modelling electricity consumption
  – Organisational dilemma
    • Need to meet the energy needs of staff
    • Need to minimise its energy consumption through effective organisational energy management policies/regulations

• Objective
  – Test the effectiveness of different electricity management strategies, and solve practical office electricity consumption problems
Questions / Comments
References

- Bonabeau (2002) Agent-based modeling: Methods and techniques for simulating human systems
- Siebers et al (2010) Discrete-event simulation is dead, long live agent-based simulation
- Siebers and Aickelin (2011) A first approach on modelling staff proactiveness in retail simulation models
- Wilensky and Rand (2013) Introduction to agent-based modeling: Modeling the natural, social and engineered complex systems with NetLogo