Computing and the Environment

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Agent (or Individual) Based Modeling
Week 4

Excerpts from "Agent-based modeling: Methods and techniques for simulating human systems" by **Eric Bonabeau**

"In ABM, one models and simulates the behavior of the system's constituent's units (the agents) and their interactions, capturing emergence from the bottom up when the simulation is run."

"One may want to use ABM when there is potential for emergent phenomena, i.e., when:

- Individual behavior is nonlinear and can be characterized by thresholds, if-then rules, or nonlinear coupling. …
- Individual behavior exhibits memory, path-dependence, and hysteresis, non-markovian behavior, or temporal correlations, including learning and adaptation.
- Agent interactions are heterogeneous and can generate network effects. …
- Averages will not work. Aggregate differential equations tend to smooth out fluctuations, not ABM, which is important because under certain conditions, fluctuations can be amplified: the system is linearly stable but unstable to larger perturbations. …"

Excerpts from "Agent-based modeling: Methods and techniques for simulating human systems" by Eric Bonabeau

"One may want to use ABM when describing the system from the perspective of its constituent units' activities is more natural, i.e., when:

- The behavior of individuals cannot be clearly defined through aggregate transition rates.
- Individual behavior is complex. Everything can be done with equations, in principle, but the complexity of differential equations increases exponentially as the complexity of behavior increases. Describing complex individual behavior with equations becomes intractable.
- Activities are a more natural way of describing the system than processes.
- Validation and calibration of the model through expert judg- ment is crucial. ABM is often the most appropriate way of describing what is actually happening in the real world, and the experts can easily "connect" to the model and have a feeling of "ownership."
- Stochasticity applies to the agents' behavior. With ABM, sources of randomness are applied to the right places as opposed to a noise term added more or less arbitrarily to an aggregate equation."

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"**Areas of Application.** Examples of emergent phenomena abound in the social, political, and economic sciences. It has become progressively accepted that some phenomena can be difficult to predict and even counterintuitive. In a business context, situations of interest where emergent phenomena may arise can be classified into four areas:

- Flows: evacuation, traffic, and customer flow management.
- Markets: stock market, shopbots and software agents, and strategic simulation.
- Organizations: operational risk and organizational design.
- Diffusion: diffusion of innovation and adoption dynamics. "

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"Flows

- **Evacuation.** Crowd stampedes
- **Flow Management.** An obvious flow management application of ABM is traffic.
- Another application of ABM to flow management is the simulation of customer behavior in a theme park or supermarket. "

"Markets

The dynamics of the stock market results from the behavior of many interacting agents, leading to emergent phenomena that are best understood by using a bottom-up approach—ABM.

IBM's Kephart and his colleagues have been exploring the potential impact of shopbots on market dynamics, by simulating and analyzing an agent-based model of shopbot economics, …"

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"Organizations

One promising area of application for ABM is organizational simulation …

The framework should be able to operate with scarce data. Hence the idea to simulate operations from the bottom up to generate a large artificial data set that includes large events.

ABM is perfect not just for operational risk in financial institution but for modeling risk in general. Modeling risk in an organization using ABM is THE right approach to modeling risk because most often risk is a property of the actors in the organization: risk events impact people's activities, not processes.

The framework should be able to operate with scarce data. Hence the idea to simulate operations from the bottom up to generate a large artificial data set that includes large events. "

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"Diffusion
In the context of this section, ABM applies to cases where people are influenced by their social context, that is, what others around them do. "

"…a simple product adoption model to illustrate the value of ABM in modeling diffusion on social networks."

An agent-based approach

- Each agent who has not already adopted has a transition probability of adopting in each time unit.

- Assume each person in the population has exactly $n = 30$ neighbors selected randomly in the population.
    - There is clustering in the topology of social interactions in that a neighbor of a neighbor is likely to be a neighbor.
    - Assume that the population is divided into two subpopulations of equal size. The probability that two individuals from the same subpopulation are neighbors is equal to P =0.5, and the probability that two individuals from different subpopulations are neighbors is equal to 0.1. In a population of 100 agents, the average total number of neighbors of any given node is 0.5*50 + 0.1*50 = 30. We assume that the initial 5% of users is within one of the subpopulations.
- The second case introduces localization in the dynamics: a person interacts only with her neighbors and there are few long-range interactions and little global mixing. …Product adoption is a lot faster with clustering, even when the initial user population is located entirely within one cluster.

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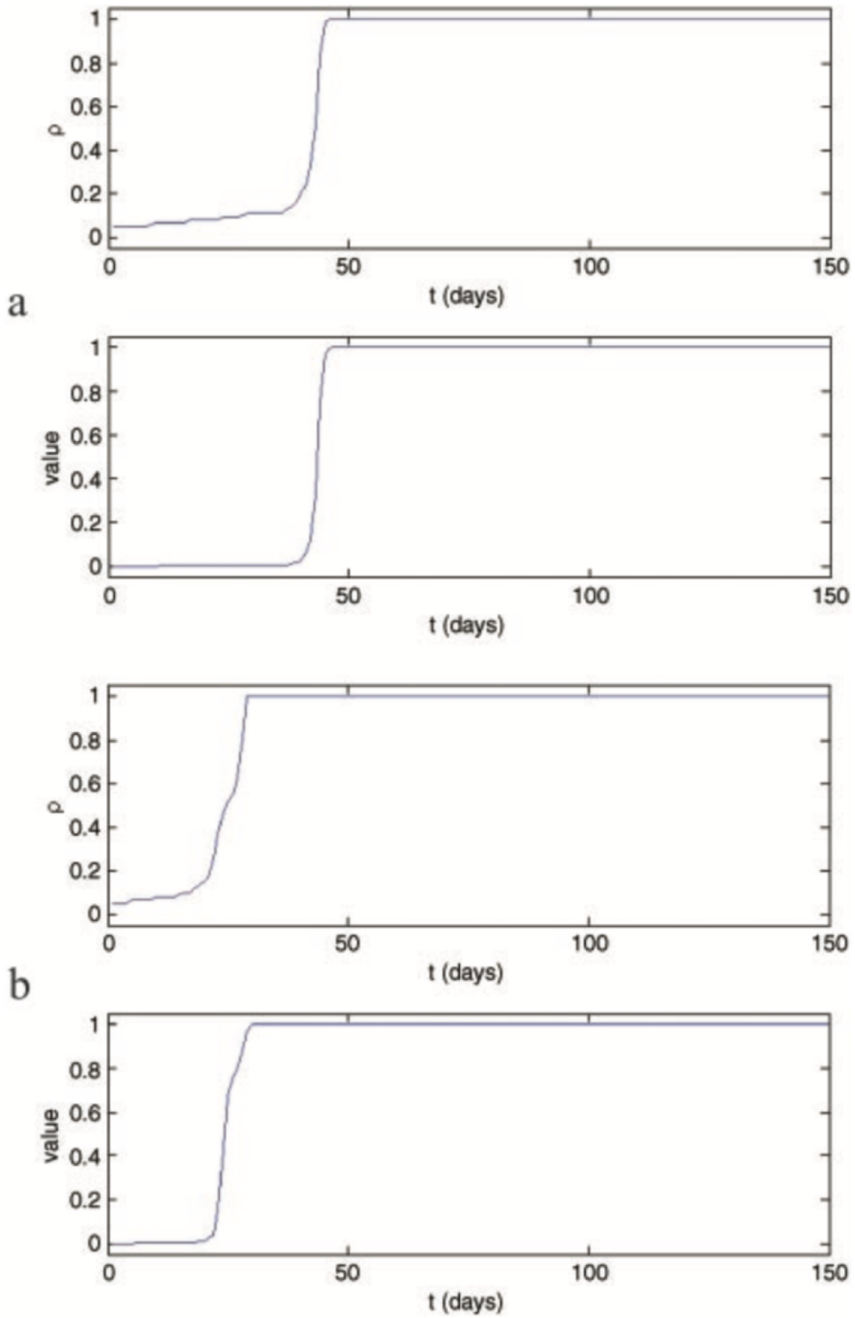

Fig. 4. (*a*) One hundred agents, 30 random neighbors. (*b*) One hundred agents, clustered neighbors (two clusters, spread starting in one cluster).

Excerpts from "A standard protocol for describing individual-based and agent-based models" *Volker Grimm, et al,* Ecological Modelling 1 9 8 (2 0 0 6) 115–126

"Simulation models that describe autonomous individual organisms (individual based models, IBM) or agents (agent-based models, ABM) have become a widely used tool, not only in ecology, but also in many other disciplines dealing with complex systems made up of autonomous entities. ***However, there is no standard protocol for describing such simulation models, which can make them difficult to understand and to duplicate.*** This paper presents a proposed standard protocol, ODD, for describing IBMs and ABMs, developed and tested by 28 modellers who cover a wide range of fields within ecology. "

Sample application of ODD

An individual- based population model of the alpine marmot, *Marmota marmota* (Grimm et al., 2003; Dorndorf, 1999).

Excerpts from "A standard protocol for describing individual-based and agent-based models" *Volker Grimm, et al*

"Lengthy verbal descriptions are the second reason why many IBM descriptions are so cumbersome. … But this need not be. Three very successful IBMs, which have been re-used and modified in numerous follow-up models, describe their basic model processes in equations: **the JABOWA forest model** of Botkin et al. (1972) and Shugart (1984), which gave rise to a full pedigree of so-called "gap models" (Liu and Ashton, 1995); **the fish cohort model** of DeAngelis et al. (1980), which initiated large research projects using IBMs (Tyler and Rose, 1994; Van Winkle et al., 1993); and **the fish school model** of Huth and Wissel (1992, 1994), which was independently re-implemented and modified several times (e.g., Inada and Kawachi, 2002; Kunz and Hemelrijk, 2003; Reuter and Breckling, 1994). **The success of these three models seems to a large degree to be due to the fact that their extensive use of the language of mathematics allowed them to be easily reproduced.** "

"**We conclude that what we badly need is a standard protocol for describing IBMs which combines two elements**: ***(1) a general structure for describing IBMs***, thereby making a model's description independent of its specific structure, purpose and form of implementation (Grimm, 2002) and ***(2) the language of mathematics***, thereby clearly separating verbal considerations from a mathematical description of the equations, rules, and schedules that constitute the model. Such a protocol could, once widely used, guide both readers and writers of IBMs. "

Figure from "A standard protocol for describing individual-based and agent-based models" *Volker Grimm, et al*

Overview	Purpose
	State variables and scales
	Process overview and scheduling
Design concepts	Design concepts
Details	Initialization
	Input
	Submodels

Fig. 1 – The seven elements of the ODD protocol, which can be grouped into the three blocks: Overview, Design concepts, and Details.

Excerpts from A standard protocol for describing individual-based and agent-based models *Volker Grimm, et al*

"2.1. Purpose
The purpose of a model has to be stated first because without knowing it, readers cannot understand why some aspects of reality are included while others are ignored. "

"2.2. State variables and scales
What is the structure of the model system? For example, what kind of low-level entities (e.g., individuals, habitat units) are described in the model? How are they described? What hierarchical levels exist? How are the abiotic and biotic environments described? What is the temporal and spatial resolution and extent of the model system? "

"2.3. Process overview and scheduling
To understand an IBM, we must know which environmental and individual processes are built into the model; examples are food production, feeding, growth, movement, mortality, reproduction, disturbance events, and management. "

"2.4. Design concepts
The design concepts provide a common framework for designing and communicating IBMs. "

Excerpts from "A standard protocol for describing individual-based and agent-based models" *Volker Grimm, et al*

"2.4. Design concepts

The design concepts provide a common framework for designing and communicating IBMs.

- *Emergence*: Which system-level phenomena truly emerge from individual traits, and which phenomena are merely imposed?
- *Adaptation*: What adaptive traits do the model individuals have which directly or indirectly can improve their potential fitness, in response to changes in themselves or their environment?
- *Fitness*: Is fitness-seeking modelled explicitly or implicitly? If explicitly, how do individuals calculate fitness (i.e., what is their fitness measure)? In agent-based models that do not address animals or plants, instead of fitness other "objectives" of the agents should be considered here (e.g. economic revenue, pollution control).
- *Prediction*: In estimating future consequences of their decisions, how do individuals predict the future conditions they will experience?
- *Sensing*: What internal and environmental state variables are individuals assumed to sense or "know" and consider in their adaptive decisions?
  Interaction: What kinds of interactions among individuals are assumed?
- *Stochasticity*: Is stochasticity part of the model? What are the reasons?
- *Collectives*: Are individuals grouped into some kind of collective, e.g. a social group?
- *Observation*: How are data collected from the IBM for testing, understanding, and analyzing it? "

Excerpts from "A standard protocol for describing individual-based and agent-based models" *Volker Grimm, et al*

"2.5. Initialization

This deals with such questions as: How are the environment and the individuals created at the start of a simulation run, i.e. what are the initial values of the state variables? Is initialization always the same, or was it varied among simulations? Were the initial values chosen arbitrarily or based on data? "

"2.6. Input

The dynamics of many IBMs are driven by some environmental conditions which change over space and time. A typical example is precipitation, which may vary over time (sea- sons, years) and space (different spatial patterns of rainfall in different regions), and management, e.g. harvesting regimes (management might also be addressed in the section "simulation experiments", which usually will follow the model description). "

"2.7. Submodels

Here, all submodels representing the processes listed above in 'Process overview and scales' are presented and explained in detail, including the parameterization of the model. "

Start Week 4 ABM exercise – you can work in groups but submit individually with a statement about who you worked with, if anyone.

https://my.vanderbilt.edu/csx892/exercise-on-agent-based-modeling/