Notes from the Field:

Practical Considerations for Agent-Based and Continuous Representations of System Dynamics

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Abstract: The increasing power and flexibility of tools available for dynamic modeling have rendered a wider range of model structures to be implemented in the study of complex systems. However, attendant with this computational capacity is the challenge of choosing between alternative model structures. To assist dynamic modelers in designing a model appropriate for the problem at hand, this paper poses a set of practical considerations for implementing agent-based and continuous representations that encode differential equations using stock-flow structures. Drawing from our collective experiences implementing system dynamics models with different structural forms, we offer recommendations for maintaining a systemic perspective while being open to a multi-method modeling process. More broadly, we take up the question of how best to leverage differential equations, agents, and potentially hybrid forms of implementation to achieve simulation insight.

Motivation:

Useful models of system dynamics rely on understanding:

1) the feedback structure of the system of interest
2) the mental models of the sentient actors

By expanding our toolkit beyond stock-flow structures to allow for agent-based representations where appropriate, we will be better equipped to develop models that enhance both kinds of understanding.

Process Note: Feedback First

No matter how a model is implemented, the modeling process should begin with a systemic perspective to hypothesize the appropriate feedback mechanisms. The "feedback first" perspective ensures that the future behavior of the model is endogenously generated.

Practical Considerations:

Transparency
The feedback structure of a system is more transparent in a stock-flow framework. However, the agent-based representation is more transparent if we need to explain why certain entities are different.

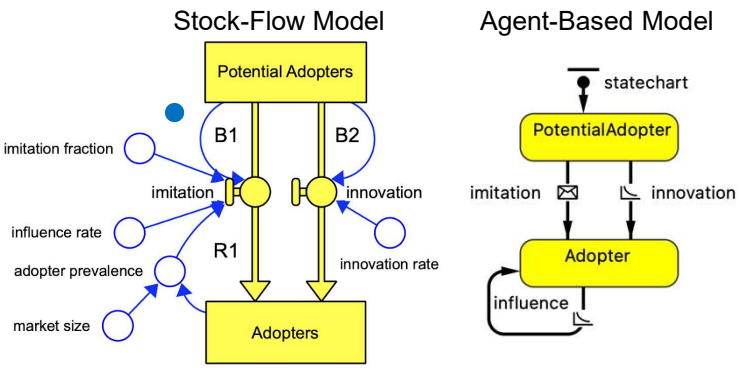
Analytical Capability
The stock-flow implementation enables methods such as steady state and loop dominance analysis. However, data science tools can be used to analyze large datasets generated by a set of differentiated agents.

Distribution of States
If the distribution of states across the elements of the system is critical to understanding the system dynamics and resulting policy analysis, then an agent-based representation is essential.

Internal Complexity
Agent-based models are advantageous when we think the agent's psychology is important. Agent-based representations of mental models also allow for hybrid forms, such as stocks of internal agent memory.

Spatial Dimensions
Spatial models warrant special consideration in simulating system dynamics. Spatial dimensions include geographic representations of space as well as other more abstract network-based representations of structure.

Example: Correspondence of Diffusion Models

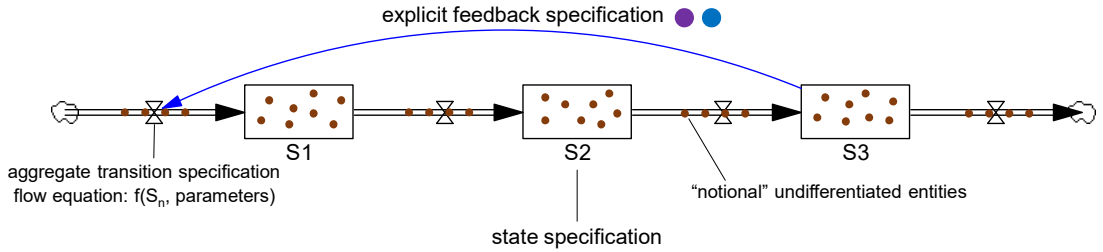


Correspondence of Structural Forms

We consider the problem space where there are two practical options for implementing a system dynamics model: stock-flow and agent-based representations.

For any system dynamics model that can be represented with stocks, flows, and feedback mechanisms, a corresponding agent-based representation could be constructed.

Stocks and Flows



Differentiated Agents