Workshop on Agent-Based Modeling of Complex Spatial Systems

Applying Agent-Based Modeling to Planning Research and Practice

I first came across the concepts and theoretical framework of complexity while pursuing an undergraduate degree in ecology. In the early 1990s in Argentina, the application of cellular automata to ecological processes was in its infancy, and agent-based modeling tools were unknown. My interest in policy, particularly affecting urban areas, increased during my work in the professional world of environmental management, a field that I found surprisingly different from ecology. The practical approaches proposed by environmental engineering aimed at linear control and growth, while the theory of complex ecological systems exhibited nonlinear relationships and required co-evolutionary change and adaptation.

In search for new knowledge to reconcile these views and to translate complexity into practical terms, I enrolled in graduate studies at the University of Michigan (UM), where I completed my doctoral degree in Urban, Technological and Environmental Planning, as well as a Certificate in the Study of Complex Systems. During my studies at UM, I was involved in the Project SLUCE (Spatial Land Use Change and Ecological Effects). This project was created to develop, evaluate and apply agent-based models of land-use and land-cover change, and assess the interactions with ecosystem functions and land-use policies. The focus was placed on the mechanisms of exurban development in Southeast Michigan, and their impacts on open space preservation. Several interdisciplinary groups were formed to develop models explaining urban sprawl and how policy can affect this pattern by implementing zoning laws and greenbelts. Another generation of models introduced the decisions made by developers, and their impact on forest cover in exurban localities. My role in this project focused on exploring the effect of land-use policy in driving land-use change.

The experience in Project SLUCE served as a stepping stone for my doctoral work, in which I integrated the hydrological dimension to the socio-economic spatial processes with which I had become familiar. I developed the Water-Use Land-Use Model (WULUM), an empirical application of agent-based modeling to study the causes and policy implications of rapidly declining groundwater levels occurring in Monroe County, Michigan. USGS hydrological studies in Monroe County suggested that land-use changes were an important factor causing the significant drawdowns observed since the 1990s. The purpose of developing WULUM was to understand the mechanisms linking land-use decisions and groundwater levels and to suggest policies to reverse the process of depletion. Through discussions with county planners around model development, WULUM allowed us to better understand the complex relationship between land-use changes and the declining water tables, as well as to explore various land-use, infrastructure and water management policy scenarios. Initial explorations with the model showed how land-use patterns might significantly contribute to groundwater declines. Both low-density and high-density zoning scenarios improved aquifer conditions over medium-density development, suggesting a non-linear relationship between intensity of residential land use and groundwater levels. Moreover, of all the natural and policy
variables, zoning had the greatest influence on urban settlement and therefore on resource consumption and supply. The agent-based representation of the problem made WULUM a suitable tool to foster discussion with the county planners around model development, rather than just around modeling outputs. In this manner, the mechanisms and parameters could be contested, adjusted and authenticated, facilitating a shared understanding of the complexity and possible surprises of the system.

My current research agenda focuses on new empirical applications of agent-based modeling to address a variety of urban sustainability issues, for which I have submitted several proposals in collaboration with interdisciplinary teams. These include:

1. Collaborative construction of agent-based models with communities across the Great Lakes Basin, coupling the socio-economic systems with the hydrology of each area. Through this setup, we seek to integrate valuable knowledge about the multiple dimensions of the problem of declining groundwater levels in the basin due to growing suburbanization, enable collective learning and innovative policy solution-building.

2. Using agent-based models to assess the sustainability of an urban system, and cope with the uncertain effects of policy. These models will integrate individual behavior in different policy scenarios, the flow of material and energy through the urban system, and natural resource dynamics. The models will be developed and applied in partnership with policy makers in the Chicago metropolitan area.

3. Building agent-based models to investigate how different perceptions of the future can introduce changes towards sustainable behavior, and test various policy alternatives to encourage those changes. We will build a series of agent-based models integrating behavioral, institutional and environmental dynamics to assess how specific combinations of parameter values in each dimension may support or impede changes in individual preferences for the sustainable use of the common resources.

The common theme in all these initiatives is diversity: of knowledge and data, interests, drivers and processes, and solutions. Agent-based models are powerful tools that can integrate this diversity, and make complexity comprehensible. A shared understanding of the complexity we face can help us assess the uncertainty inherent in coupled systems, contest and validate modeling assumptions, and provide creative and meaningful planning solutions.