Modeling Complex Urban Landscape Dynamics:
A Pattern-Oriented Hierarchical Approach

Workshop on Agent-Based Modeling of Complex Spatial Systems

Santa Barbara April 14-16, 2007

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As complex dynamic systems, urban landscapes emerge from the local interactions of socioeconomic and biophysical agents and processes. These complex systems are highly heterogeneous, spatially nested, and hierarchically structured (Wu and David 2002). They are prototypical complex adaptive systems, which are open, nonlinear, and highly unpredictable (Levin 1998, Portugali 2000, Gunderson and Holling 2002). Patterns emerge from numerous locally made decisions involving multiple human and biophysical agents interacting among themselves and with their environment. These agents are autonomous, adaptive and change their rules of action based upon new information. Interactions within this complex domain between agents and processes are scale dependent.

While important progress has been made in modeling complex human and natural systems, the ability to simulate emergent behavior in ways that reasonably capture patterns observed in urban landscapes remains a significant research challenge. One major challenge in modeling urban landscape dynamics is in representing explicitly the human and biophysical agents at a level of disaggregation that allows us to explore the mechanisms linking patterns to processes (Portugali 2000). A second challenge in modeling the interactions between human and natural systems is that many factors operate simultaneously at different levels of organization. Additionally, since urban landscapes are spatially heterogeneous, changes in driving forces may be relevant only at certain scales (Turner et al. 1995). Yet our current understanding of the interactions between spatial scales is limited. Simulating the behavior of urban landscapes requires not only an explicit consideration of the temporal and spatial dynamics of these systems, but it also requires identifying the interactions between human and biophysical agents across the different temporal and spatial scales at which various processes operate.

A new Biocomplexity research project at the University of Washington (UW) and Arizona State University (ASU) aims to develop a new framework for modeling the complex coupled human-natural system dynamics of Seattle and Phoenix metropolitan areas.* We propose a pattern-oriented hierarchical approach to model how complex agent-based interactions generate landscape patterns at multiple temporal and spatial scales. We hypothesize that similarly to other ecosystems described by Scheffer et al. (2001), in urban landscapes changes from one state (characterized by a set of processes) to another (characterized by a new set of processes) can be triggered either by the action of slowly changing variables or by relatively discrete shocks. We hypothesize that urban landscapes are spatially nested hierarchies in which the hierarchical levels correspond to structural and functional units (Wu and David 2002). Using a hierarchical modeling approach we aim to identify the structural and functional units at distinct spatial and temporal scales of human and biophysical processes and specify the agents and rates of processes that characterize and distinguish the levels in the hierarchy. The hierarchical patch dynamics perspective emphasizes both the vertical structure (linkages between scales or organizational levels) and horizontal structure (spatial patterns) of the urban landscapes (Wu and David 2002). This perspective allows for a more realistic representation of the relationships among patterns, processes, and scales that lead to emergent properties of heterogeneous urban landscapes.

We specify this model using a spatially explicit, agent-based approach. The model will incorporate the hierarchical patch dynamic modeling approach: such a strategy allows an explicit representation of the nested organizational hierarchies present in human-biophysical systems and thereby provides an elegant means of understanding the interconnections between hierarchical levels. We implement this approach using a hybrid method that integrates dynamic probabilistic relational model (DPRM) and an agent based model. Using DPRM, parameters and spatial rules are estimated empirically from two longitudinal land cover and land use data sets developed for the Seattle and Phoenix Metropolitan Areas.

*For a description of this project see: BE/CNH: Urban Landscape Patterns: Complex Dynamics and Emergent Properties. Alberti, M. (PI), Wu, J., Redman, C., Marzluff, J., Handcock, M. Anderies, J. M., Waddell, P., Fox, D. and H. Kautz. NSF Biocomplexity 2005-2009.

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