Representing geographic dynamics

Thomas J. Cova, Associate Professor, Department of Geography
University of Utah, 260 S. Central Campus Dr., Rm. 270,
Salt Lake City, UT 84112-9155, cova@geog.utah.edu, Voice: 801-581-7930

A number of related yet distinct subfields of GIScience associated with representing geographic dynamics have recently emerged. Researchers in spatio-temporal theory and data modeling, spatial process modeling, complex systems, and agent-based modeling all consider dynamic (or temporal) aspects of geographic phenomena germane to their respective specialty. Given this common ground, an obvious question arises as to the degree to which these communities have shared goals that might be forwarded through collaboration. In short, where might synergies or unique insights lie, and what redundant efforts might be streamlined? This short position paper looks at two research areas (and communities) that are the focus of this workshop: agent-based modeling and spatio-temporal data modeling.

Agent-based modeling of complex systems

Agent-based modeling is an active research area that continues to gain momentum. The software tools to support this type of modeling have come a long way both in terms of facilitating rapid model development as well as integrating models with GIS. The area also evolved from the start with a particular emphasis on explicit representation of space despite having no relation to the GIScience community. In general, researchers in this area are concerned with modeling geographic processes "from the bottom up" in a quest to understand emergent phenomena at a macro scale form micro interactions. A common approach is to generate *synthetic* populations and landscapes where autonomous, intelligent agents can interact with their environment and each other. Although the landscapes represented are often based on real places, the notion that the population is synthetic implies that the correspondence with actual agents in the real world is secondary to the goal of discovering emergent outcomes at the macro scale. For example, it's more important to reveal global patterns of segregation in a hypothetical city than it is to represent any real agent, building or event. In some cases, agents may adapt to, or learn from, their surroundings. In this way, agents are typically ephemeral. Validity and accuracy therefore generally refer to the degree to which a model corresponds with a given process rather than whether any object, interaction or event is positioned correctly in space-time (or can be recovered through query).

Spatio-temporal data modeling

In contrast to agent-based modeling, research in spatio-temporal data modeling tends to focus on accurately depicting real world geographic phenomena as objects, fields, events and processes in such a manner that their histories and interaction can be queried, reconstructed or predicted. Mining large data sets that represent spatio-temporal phenomena is a current theme. Maintaining or tracking an object's identity through time is also important, as is assessing the accuracy of a field or object attribute at time *t*. An

example object in this research context might be a delivery truck traveling across the country, a field might be the anticipated precipitation along the route, and an event might be "leaving Iowa" or "entering a storm cell". Field-object hybrids have been proposed to deal with unique phenomena like weather or wildfire (Yuan, 2001; Cova and Goodchild 2002) along with models that focus on the inter-relationships between objects, events, and processes (Worboys and Hornsby 2004). Recent work has emphasized the search for an underlying theoretical level that might underpin all geographic representation (Goodchild et al. 2007). In any case, the concepts of synthetic populations, emergence, complexity and adaptiveness are generally foreign to this area, despite the similar focus on geo-dynamics shared with researchers in complex systems and agent-based modeling.

Combining efforts

What would a union between the sub-fields of complex adaptive systems (or agent-based modeling) and spatio-temporal data modeling yield? One outcome might be a subfield (or associated software platform) that can model adaptive agents and their interactions with an eye to identifying emergent phenomena, yet also allow for greater data mining or querying of object and field dynamics or events to reconstruct scenes with a close (or accurate) relationship with real world states. The theories and software tools in the two areas seem to have developed from entirely different goals, and it's difficult to visualize one platform that would satisfy specialists from both areas. A recent call from the point of view of spatio-temporal theory for research into data structures (Galton 2004) emphasizes how far behind this area is from the easy-to-acquire and install software platforms to support agent-based modeling. Similarly, recent papers from spatial-temporal data modeling tend to emphasize how difficult it is to advance this area given the problems that time presents (Peuquet 2001; O'Sullivan, 2005). The notion of a workshop to explore the benefits of cross-fertilization of these two areas is likely to yield very interesting and fruitful research and development directions for both areas.

References

Cova, T.J. and Goodchild, M.F. (2002) Extending geographical representation to include fields of spatial objects. International Journal of Geographical Information Science, 16(6), 509-532.

Galton, A. (2004). Fields and Objects in Space, Time, and Space-time. *Spatial Cognition and Computation*, 4(1), 39-68.

Goodchild, M.F., Yuan, M., and Cova, T.J. (2007) Towards a general theory of geographic representation in GIS. *International Journal of Geographical Information Science*, 21(3), 239-260.

O'Sullivan, D. (2005). Geographical information science: time changes everything. *Progress in Human Geography*, 29(6), 749-756.

Peuquet, D. (2001). Making Space for Time: Issues in Space-Time Data Representation. *Geoinformatica*, 5(1), 11-32.

Worboys, M.F. and Hornsby, K. (2004). From Objects to Events: GEM, the Geospatial Event Model. *Lectures Notes in Computer Science*, 3234, 327-343.

Yuan, M. (2001). Representing complex geographic phenomena in GIS. *Cartography and Geographic Information Science*, 28(2), 83-96.