LEAM: Extended Cellular Automata Model of Urban Land-use Change

Zhanli Sun
111 Temple Buell Hall
611 Taft Drive
Champaign, IL 61820
Email: sun2@uiuc.edu
Phone: 1-217-265-0217

BIOGRAPHY

Post-doc Research Associate, Department of Urban and Regional Planning University of Illinois at Urbana-Champaign. He got his Ph.D. (Geographic Information System and Cartography) from Institute of Geography, Chinese Academy of Sciences, 1999. He has broad research interests in spatial information theory and technology, including spatial modeling, spatial data handling, and system development. His recently focuses his research interests upon Decision Support System (DSS) for urban planning by employing System Dynamic (DS) concept and Cellular Automata.

ABSTRACT

Cities are complex systems that arise through a complex interaction of many factors. As a result, the mechanism of urban growth and its interaction with social, economic and environmental systems are still poorly understood. Policy makers and planners often face tremendous difficulties in decision making with a lack of vision into the future of urban growth.

Due to the complexity nature, cities can be best understood by spatial dynamic modeling using complex system tools. Cellular Automata are discrete dynamical systems whose behavior is completely specified in terms of a local relation. In a typical two dimension cellular automaton, space is represented by a uniform grid, with each cell holding a discrete value as its state. The cell state changes in discrete steps and its new state is computed based on the configuration of its neighbor cells. CA is embedded with a spatial dynamic feature, which makes CA a natural tool for spatial modeling. CA is very appealing to geographic modelers because

1) CA based model is simple and intuitive, yet capable to simulate self-organizing complex system;

2) The natural born spatial dynamic feature enables modeling spatial dynamic system in extreme spatial detail and spatial explicitly;

3) The cellular structure of CA has natural affinity with raster data format of Remote Sensing images and GIS grid map. CA model can be easily integrated with GIS through generalization of map algebra (Takeyama and Couclelis, 1997);

4) The bottom-up approach of CA provides a new strategy of geographic modeling;

5) CA is computational model running in parallel which fits the high-performance geo-computation.

In the past few decades, CA application in geography has been experiencing exponential growth, especially in urban land-use simulation (Batty and Xie, 1994; White and Engelen, 1997; Clarke and Gaydos, 1998; Wu and Webster, 1998; Li and Yeh, 2002)

Although a large number of models have been proposed and built over the last twenty years, CA based on land-use modeling technique is still far from being mature. Despite the flexibility of the CA approach, limitations remain (Torrens and O'Sullivan, 2001). The hypothetical urban forms emerging from CA models with surprisingly simple local transition rules are certainly plausible. However, urban system evolves in a much more complex way in reality. The current CA-based urban models are just too simple to capture the richness of urban systems. Consequently, very few CA models are operational and are used as productive tool to support regional planning practice. To build useful models, modelers need to extend the concept of CA, and also integrate a diversity of models, such as traditional regional social-economic models.

Extending CA concepts, the Land-use Evolution and impact Assessment Model (LEAM) has been developed as a comprehensive urban planning support system on a regional scale that simulates land-use change across space and time. In LEAM, cells evolve in a constrained surface defined by biophysical factors, such as hydrology, soil, geology and land form, and social-economic factors, such as administrative boundary, census district, instead of a homogeneous space as in traditional CA model. The probability of each cell change is not only decided by the local interactions of neighbor cells, but also by global information. Therefore, cells in LEAM are intelligent agents which can not only get the local information, but also sense the regional or global information, like social environment and economic trend.

LEAM incorporates ecological, economical, social, geographic, and environmental theories into a single hierarchical framework. LEAM is unique in that all sub systems are explicitly and separately modeled, each developed by experts with substantive knowledge in a particular fields These contextual sub-models are then linked to form the main framework of the dynamic model that run simultaneously on each grid cell of raster GIS map(s) in Spatial Modeling Environment (SME) (Maxwell and Costanza, 1997). The overall model then is created in an open and distributed manner.

LEAM helps to examine and comprehend the complex relationships between what drives growth, where growth is likely to occur (under a variety of scenarios), and the potential positive and negative impacts. The products of LEAM model runs are a series of GIS maps or movies that show the transformation of the landscape for a particular region as a product of various policies and their associated economic, social, and environmental impacts. The LEAM approach has been developed and successfully applied for the St. Louis bi-state region and the Chicago metropolitan area.

REFERENCES

Batty, M., and Y. Xie. 1994. From Cells To Cities. Environment And Planning B-Planning & Design **21**:S31-S38.

Clarke, K. C., and L. J. Gaydos. 1998. Loose-coupling a cellular automaton model and GIS: long-term urban growth prediction for San Francisco and Washington/Baltimore. International Journal Of Geographical Information Science **12**:699-714.

Li, X., and A. G. Yeh. 2002. Neural-network-based cellular automata for simulating multiple land use changes using GIS. International Journal Of Geographical Information Science **16**:323-343.

Maxwell, T., and R. Costanza. 1997. An open geographic modeling environment. Simulation **68**:175-185.

Takeyama, M., and H. Couclelis. 1997. Map dynamics: Integrating cellular automata and GIS through Geo-Algebra. International Journal Of Geographical Information Science **11**:73-91.

Torrens, P. M., and D. O'Sullivan. 2001. Cellular automata and urban simulation: where do we go from here? Environment And Planning B-Planning & Design **28**:163-168.

White, R., and G. Engelen. 1997. Cellular automata as the basis of integrated dynamic regional modelling. Environment And Planning B-Planning & Design **24**:235-246.

Wu, F. L., and C. J. Webster. 2000. Simulating artificial cities in a GIS environment: urban growth under alternative regulation regimes. International Journal Of Geographical Information Science **14**:625-648.