Agent-Based Modeling in Crime Analysis and Simulation

Submitted to the Workshop on Agent-Based Modeling of Complex Spatial Systems

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Agent-based modeling in crime analysis and simulation is an emerging research area that started about six years ago by a relatively small group of environmental criminologists and geographers. The collaboration between Dr. Lin Liu at the Department of Geography and Dr. John Eck at the Criminal Justice Division at the University of Cincinnati represents one of the leading efforts in propelling research in this area. In this proposal, we will briefly describe agent-based crime simulation, and then explain our qualification in relation to the workshop.

1) Agent-based simulation

Many crime analyses attempt to model the relationships between crime and various contributing factors. Researchers typically aggregate their measures to varying area units to avoid modeling the processes of how individual participants’ decisions give rise to crime events and how these events coalesce to form crime patterns. Although they are useful for describing aggregate crime patterns, they cannot reveal the underlying mechanisms that generate crime patterns.

In this study, we simulate the micro-level decision processes that give rise to crime events. It applies criminology theories and reasonable assumptions to explicitly model the decisions and actions of agents. These processes generate individual crime events, and the accumulation of these events then forms crime patterns. The theoretical basis of the crime simulation model is the routine activities (RA) theory and the rational choice theory. Offenders, targets and crime places, the three basic elements of routine activities, are modeled as individual agents. The properties and behaviors of these agents change in space and time. The influence of police agent is also investigated in the study. The interactions of these agents are modeled in a cellular automaton (CA). Tension, measuring the psychological impact of crime events to human beings, is the state variable of the CA.

Our conceptual framework is named SPACES - Spatial Adaptive Crime Event Simulation. The agents are intelligent and adaptable in their behavior and spatial movement. They learn from past offending and victimization experience, and adjust their future behavior accordingly. For example, target agents move along street as part of their routine activities. The exact travel path they take is influenced by network proximity and crime risk. As new crime events change the spatial distribution of risk, target agents adjust their path using a heuristic reinforcement learning algorithm. At the same time, offenders seek opportunities and adjust their spatial movement based on the reward/penalty of their past experience.

We have used this simulation model as a virtual laboratory to uncover the interplay of multiple criminology theories. Analysis of simulated data reveals plausible crime patterns and helps generate hypotheses. The model is also used to examine possible future crime patterns based on different policing and law enforcement strategies. A snapshot of the implemented prototype system is inserted in the next page.
Our experiences with modeling crime events and patterns suggest that crime simulations, like other agent-based simulation, cannot escape from the difficult challenge of model calibration. Due to the non-linear nature of the model and a large number of parameters, calibration of the model is not an exact science. Nevertheless, we have had some success in matching simulated patterns to real crime patterns that may advance understanding of how to calibrate and validate simulation of complex spatial systems.

2) Qualification

We first presented our work on agent-based crime simulation six year ago at the 2001 UCGIS Summer Assembly, and we have since published two articles on this topic. We are also invited speakers to present at an NSF workshop on Crime Hot Spots: Behavioral, Computational and Mathematical Models, in UCLA, January 29 - February 2, 2007.

We are currently editing a book titled *Artificial Crime Analysis Systems: Using Computer Simulations and Geographic Information Systems*, to be published later this year. This edited volume brings together the leading researchers in the use of computer simulation of crime patterns to create a keystone source for this developing field. We have received 20 chapters from scholars in U.S., U.K., Canada, The Netherlands, Australia, China, and Brazil. These chapters describe the theory, method, and application of crime pattern simulations. Our goal is to produce a volume that everyone studying or conducting research in this area must reference. This book has the potential of being a catalyst that accelerates the research in crime simulation.

Being the editors of this book, we are in a unique position to provide a comprehensive assessment of the current development in the area of crime simulation.