Investigating Integrated Space-Time Representations in Epidemic Agent-based Modeling:
A CyberGIS Use Case

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Epidemic agent-based models (ABMs) simulate individuals in artificial societies capable of moving, interacting, and transmitting disease amongst themselves. Aimed to improve epidemic preparedness, scientists and policy makers at state and national levels increasingly use agent-based simulations to understand how disease spreads through populations, space, and time (Epstein, 2009). While the finest-grained representations of space and time are considered critical factors (Batty et al., 2012), they are often coarsened in large-scale epidemic ABMs consisting of tens of millions of agents due to limitations in data and computation. To gain systematic understanding of how space-time representations influence simulated disease spread in epidemic ABMs this paper suggests leveraging cyberGIS, broadly defined as cyberinfrastructure-enabled geographic information systems, to overcome multiple challenges (Wang, 2010).

Simulating the fine-grained movements and interactions of millions of agents represents a significant computational challenge (Prieto et al., 2012). The exploitation of high-performance computing (HPC) is quickly being adopted by ABMs to overcome this challenge with recent work focusing on improving the efficient and scalable use of HPC (Shook et al., 2013). CyberGIS provides ABMs not only access to HPC resources, but also geographic information services and spatial middleware to help manage the executions and resultant data of thousands of simulations (Wang, 2010).

Large-scale ABMs also face a "big data" challenge (Shook and Wang, 2011). Input data for epidemic simulations may include individual-level demographic information; building locations and capacities; or movement patterns of cars, buses, or planes. Additionally, epidemic ABMs are capable of producing massive amounts of spatial-temporal data representing locations, interactions, and infections of agents throughout potentially thousands of simulations. Successfully leveraging cyberGIS may help to handle these big data thus enabling the examination of spatial and temporal patterns of simulated disease spread.

Space-time representations are interwoven into the underlying assumptions of epidemic simulations and unmasking their influence on simulated human behavior and movement patterns is a challenging task. Modelers and experts from diverse areas may be needed to fully appreciate the interrelationships between space-time representations and the varying

processes within large-scale epidemic ABMs. CyberGIS offers a collaborative environment supported by tools and intuitive interfaces that can be used to configure, visualize, and analyze simulations, which will help to foster collaborative research and knowledge sharing amongst epidemic modelers and experts.

This paper suggests leveraging cyberGIS to overcome multiple challenges thus opening new avenues of exploration in the investigation of space-time representations in epidemic ABMs. Recent work using a novel modeling approach as part of a cyberGIS-enabled epidemic ABM demonstrate that variations in the finest-grained representations of space and time alter disease spread dynamics. Specifically, coarsening space-time representations is shown to alter the speed, intensity, and spatial spread of disease in an agent-based simulation of the state of Ohio. A practical implication of these findings suggest that disease risk may be over- or under-estimated in rural versus urban areas, which could affect broader understanding of epidemic modeling results. This recent work represents a first step not only toward examining the influence of space-time representations, but also as a solid use case in leveraging cyberGIS to enable large-scale agent-based simulations.

References

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