CyberGIS-Jupyter for Spatially Explicit Agent-Based Modeling: A Case Study on Influenza Transmission

Alexander Michels, Jeon-Young Kang, Jared Aldstadt, Rebecca Vandewalle, and Shaowen Wang
Department of Geography and Geographic Information Science, College of Earth, Society, & Environment, University of Illinois at Urbana-Champaign

Abstract

Despite extensive efforts on achieving reproducible agent-based models (ABMs) to improve the capability of this widely adopted methodology, it remains challenging to reproduce and replicate pre-existing ABMs, due to a number of factors such as diverse computing resources and ABM platforms. In this study, we propose to employ CyberGIS-Jupyter for spatially explicit ABM modeling. CyberGIS-Jupyter is a cyberGIS framework to achieve data-intensive, reproducible, and scalable geospatial analytics using Jupyter Notebook based on advanced cyberinfrastructure. Influenza transmission in the city of Miami, Florida, USA was used as a case study. In the model, Influenza is transmitted through the contact networks of individual human agents, which are constructed based on commuting behaviors. CyberGIS-Jupyter can support collaborative and transparent modeling, but also to performing simulation model on advanced cyberinfrastructure resources. It may contribute to boosting the reproducibility and replicability of ABMs.

Methods

Our model for influenza transmission is network-based and follows the SEIR model which stands for:
- Susceptible
- Exposed
- Infectious
- Recovered

Agents in our model are connected through a contact network. In our graph, agents are nodes and agents are connected if they are in the same location at the same time, with edge weights that specify what proportion of their day the agents are in the same location. For example, agents spend time with their family and with their coworkers/classmates depending on age. Putting together the contact networks from the agent’s various settings, we get a contact network that represents the daily activities of all of our agents.

Analysis

Our model allows users to visualize and analyze the components and outputs of the model.

To the right, you can see:
- A visualization of the contact network
- A map of the spatial distribution of the influenza cases
- A frame of a movie which shows spatio-temporal patterns of cases
- A graph comparing the temporal distribution of cases from the model to the observed data

In agent-based modeling, the parameters of the model can have large effects on the model outputs, so we added simple sliders to allow researchers to run our experiments with any set of model inputs they like and analyze their outputs.

Conclusions

In spite of efforts on transparent descriptions of ABMs to improve modeling outcome, ABM models often encounter challenges associated with reproducibility and replicability of pre-existing ABMs. Modeling environments may vary due to many factors such as computing resources and ABM platforms. Therefore, it is still a significant challenge to conduct collaborative ABM research and development across various domains and topics.

To tackle this challenge, we apply CyberGIS-Jupyter for spatially explicit agent-based modeling to boost reproducibility and replicability. CyberGIS-Jupyter is established to achieve data-intensive, reproducible, and scalable geospatial analytics with Jupyter Notebook serving as the primary user environment. CyberGIS-Jupyter enables one not only to share modeling codes and comments but also to run and improve models in a transparent and incremental fashion. In addition, it is feasible to reproduce modeling workflows, based on common data sources and modeling structures.

Uncertainty and sensitivity analysis would be an apparent next step for future research as a means of evaluating quality and validity of the model and measuring specific effects of model parameters on mismatches to observed patterns. Such future work will provide a deeper understanding of the model itself and the phenomenon of influenza transmission. Then, parameter adjustments through reproducible calibration can help discover patterns of influenza with high confidence.

References


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