CyberGIS-Jupyter for Spatially Explicit Agent-Based Modeling:

A Case Study on Influenza Transmission

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Reproducibility in Science

Reproducible science requires that the results of an experiment or study can be reproduced (to a reasonable extent) when other scientists carry out the same experiment or study with the same methodology. Many researchers have discovered a reproducibility crisis in within their fields and a 2012 study in *Nature* found that 47 out of 53 medical research papers in cancer research were irreproducible [1]. This problem is exacerbated in the computational sciences such as Agent-Based Modeling and Geographic Information Science due to differences in computational environments, data processing techniques, and access to computational resources.

In an attempt to foster more reproducible work, we used the CyberGIS-Jupyter platform to build and host an agent-based model for influenza transmission where scientists can run the model, vary inputs, and analyze outputs themselves without concerning themselves over reproducing the computational environment or obtaining data.

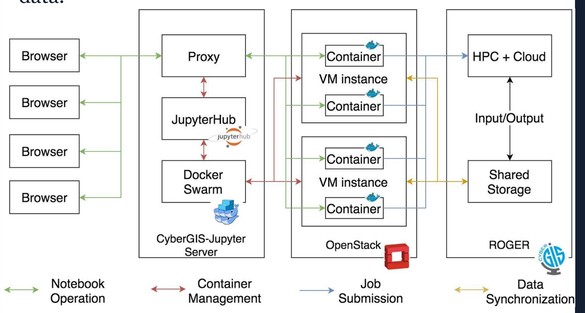


Diagram of the CyberGIS-Jupyter cyberinfrastructure

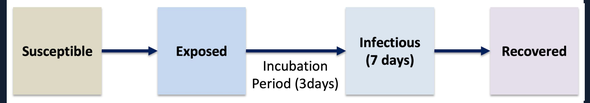
Abstract

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 ABMs platforms. In this study, we propose to employ CyberGIS-Jupyter for spatially explicit ABMs. 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 one not only to conduct collaborative and transparent modeling, but also to perform modeling simulation on advanced cyberinfrastructure resources. It may contribute to boosting the reproducibility and replicability of ABMs.

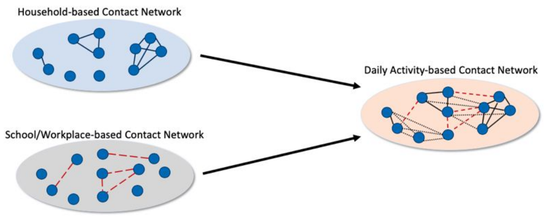
Methods

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

- Susceptible
- Exposed
- Infectious
- Recovered

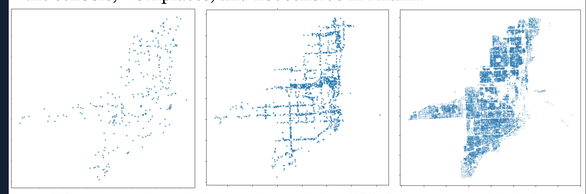


Agents in our model are connected through a **contact network**. In our graph, agents are nodes and agents are connected if they are in the same location at the same time, with edge weights that specify what proportion of their day the agents are in the same location. For example, agents spend time with 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.

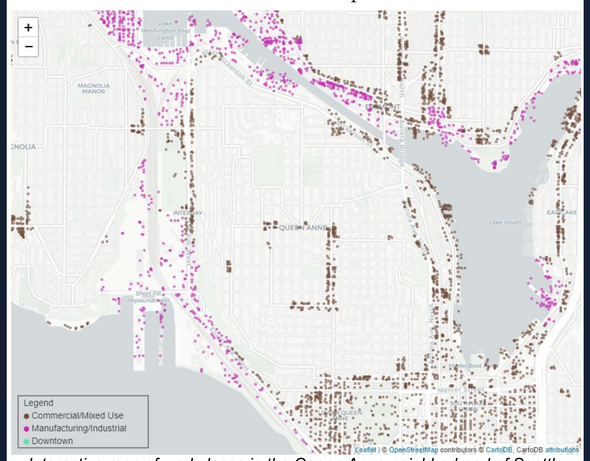


Our Setting

For our initial model, the setting was Miami, Florida. Below are the schools, workplaces, and households in Miami.



When we adapted the model to CyberGIS-Jupyter we added data to run the model in more locations. We also added interactive maps and visualizations so researchers could explore our data.



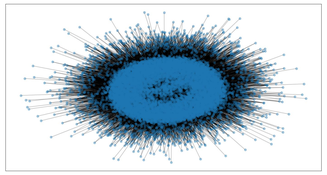
Interactive map of workplaces in the Queen Anne neighborhood of Seattle

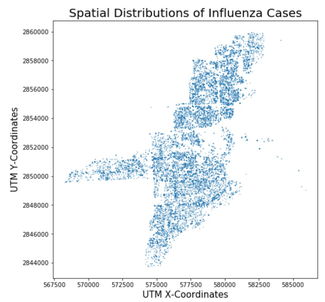
Analysis

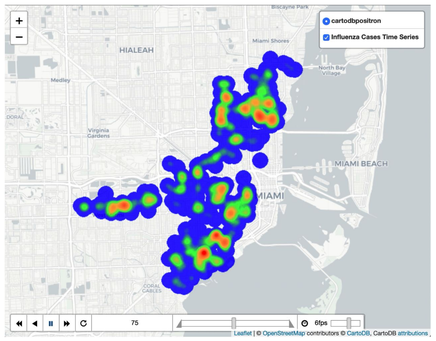
Our model allows users to visualize and analyze the components and outputs of the model.

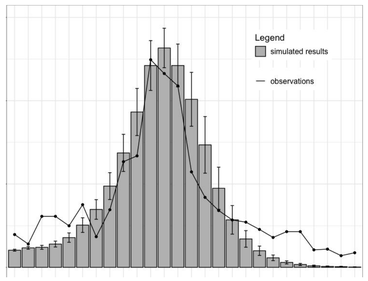
To the right, you can see:

- 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

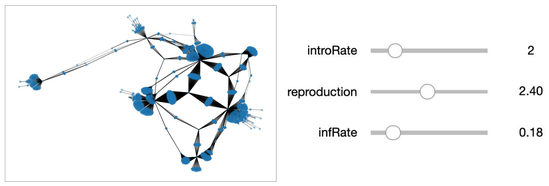








In agent-based modeling, the parameters of the model can have large effects on the model outputs, so we added simple sliders to allow researchers to run our experiments with any set of model inputs they like and analyze their outputs.



The contact network for a subset of Queen Anne and a slider for parameters

Conclusions

In spite of efforts on transparent descriptions of ABMs to improve modeling outcome, ABM modelers 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

[1] Begley, C. G.; Ellis, L. M. (2012). "Drug development: Raise standards for preclinical cancer research". Nature. 483 (7391): 531–533. doi:10.1038/483531a. PMID 22460880.

[2] Kang, J.-Y., Aldstadt, J., Michels, A., Vandewalle, R., & Wang, S., (2019), CyberGIS-Jupyter for spatially explicit agent-based modeling: A case study on influenza transmission, *ACM SIGSPATIAL'19 Geospatial Simulation Workshop*

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