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CITYCOVID: A COMPUTER SIMULATION OF COVID-19 SPREAD IN A LARGE-URBAN AREA

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ABSTRACT

CityCOVID is a city-scale agent-based model of millions of people in a large metropolitan area, currently the Chicago area. CityCOVID is being used to understand the possible spread of COVID-19 and to model the uncertainties of human behavior in response to public health interventions. This paper describes the model and its application in the COVID-19 crisis, and its use to support decision making at the city, county and state levels.

1 INTRODUCTION

CityCOVID is a city-scale agent-based model of millions of people in a large metropolitan area, currently the Chicago area, based on the ChiSIM modeling framework (Macal et al. 2018), parallelized for running on high performance computers (Collier et al. 2015). Individual people are represented as software "agents" in the model, each agent having a set of characteristics (such as socio-demographics, neighborhood of residence, etc.) and behaviors (such as their schedules of where and when people go outside the home, how they react to having a disease, or in response to a stay-at-home-order, etc.). Agents consist of a synthetic population of the 2.7 million Chicago residents (Kaligotla et al. 2018). Places consist of geo-located parcels in the city, such as households, schools, workplaces, hospitals, and general quarters, such as nursing homes, dormitories, jails, etc. (1.2 million locations). During a simulated day, agents move from place-to-place, hour-by-hour, engaging in social activities and interactions with agents who are located at the same place and engaged in the same activity. CityCOVID has been described as "SimCity on steroids."

2 MODELING DISEASE TRANSMISSION IN CITYCOVID

CityCOVID simulates the possibilities for agent-to-agent transmission of disease such as COVID-19 as a result of the contacts of co-located agents. Effectively, CityCOVID generates endogenous co-location networks (Tatara et al. 2017). The detail time dynamics of SARS-CoV-2 transmission and progression through COVID-19 disease states are included in the model. When simulated over hours, days, weeks and months, CityCOVID recreates the dynamics of likely disease spread through the entire population. Each simulation scenario is based on a set of assumptions concerning government interventions and agent

behaviors in response to the interventions and to having the diseases. The assumptions are informed by the data and the literature, which are updated regularly as more information becomes available on COVID-19.

Given the inherent uncertainties surrounding how people will behave, we attempt to capture, through large numbers of stochastic simulations and possible future scenarios, run on Argonne Leadership Computing Facility resources, over the range of possible epidemic trajectories. Where machine learning plays a central role in our work is through the algorithms we use to calibrate our models and to capture uncertainties in our model parameters (Ozik et al. 2018). We use a variety of Bayesian and other techniques to do this, and are somewhat uniquely able to run these complex algorithms at the requisite scales as high-performance computing workflows. Machine learning algorithms also come into play when we construct the attributes and behaviors of our synthetic agents that make up our model population, for example in assigning underlying health conditions or differential access to medical care across the city.

3 CITYCOVID USES

Tens of thousands of simulations have been run to investigate the impact of interventions on COVID-19 spread. Because of the individual level of detail for representing the agents as well as the heterogeneity, results for specific areas (zipcodes, for example), groups (age groups, for example) can be discerned from the model output. For example, recent runs compared scenarios of population disparities across Chicago neighborhoods and looked at the contribution to hospitalizations by age group.

Many questions are being addressed by CityCOVID including the following:

- Will there be a second wave? When and how bad will it be?
- Are some communities and neighborhoods being disproportionately affected?
- What is the impact of school reopening strategies on the spread of COVID-19 throughout the community?
- How can we set up an effective testing program and an effective contact tracing program?
- When will the COVID-19 pandemic end and when can we can go back to a normal way of life?

Results of CityCOVID simulations are regularly conveyed to city, county and state public health officials.

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