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ANALYZING COVID-19 CONTROL STRATEGIES IN METROPOLITAN AREAS: A CUSTOMIZABLE AGENT-BASED SIMULATION TOOL

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ABSTRACT

With the rapidly changing dynamics and understanding of Covid-19, the need to analyze the efficacy of possible mitigation strategies has never been higher. Such strategies may include social distancing, mask-wearing, school/business closures, random testing, and quarantines of differing lengths. We develop an agent-based simulation tool that can be customized to simulate any city chosen. Data regarding distribution of household size, age groups, commute patterns, preexisting health condition prevalence, and school and business assignments are used as inputs. In this presentation, we calibrate the simulation for the case of New York City as a test bed as the city soon became the epicenter of the outbreak in the United States. The simulation tool will be made publicly available and can be used by government officials and other decision makers as a decision support tool to perform what-if analysis and design effective mitigation strategies for metropolitan areas based on various metrics.

1 INTRODUCTION

We propose a decision support tool involving a generalizable and customizable agent-based simulation model developed in Repast Simphony that allows for any city to create a fine-grained simulation of the corresponding real-world population and their interactions. For the sake of this presentation, we illustrate the applicability of the proposed tool by evaluating different random testing strategies in a case study of New York City (NYC) related to the Covid-19 outbreak. Random testing is critical for public health as it enables understanding the virus spread in populations, establishing level of herd immunity in communities, estimating the true fatality rate, and making decisions about mitigation efforts such as how and when to adjust social distancing interventions. With the increased availability of rapid Covid-19 tests, many countries (including the United States) are contemplating or implementing such testing strategies.

2 THE AGENT BASED SIMULATION TOOL

2.1 Input

Table 1 summarizes the key input data categories (along with examples) that are used in the simulation tool to generate the population and model the spread of an infectious disease.

Table 1: Main categories of input data and sample input parameters.

Commute Patterns	Mitigation Strategy	Disease	Population
Public transportation usage	Number of daily tests	Incubation period	Age group distribution
(e.g., from/to flow matrix)	Quarantine duration	Infectious period	Household size distribution
Station locations	School/business closure	Fatality rate	Preexisting health issues

2.2 Population Generation

Each agent is assigned to a household and either a workplace or school/university based on their age (some may be unemployed). Schools/universities are assigned to their real-world location. Students are assigned to the closest school that has capacity for their grade. For the NYC case, we use census data to create households and workplaces of different sizes in the census tract they belong to. Moreover, data from the US Department of Health and Human Services are used for preexisting health conditions in NYC boroughs.

2.3 Disease Spread and Testing

In each gathering of agents, the disease has a chance of spread. For each type of gathering (workplace, home, community, classroom, etc.), there is a parameter for "mean number of contacts" and "probability of transmission" from an infectious agent to a susceptible agent. Different levels of social distancing and mask-wearing effectiveness can be modeled by adjusting these parameters. For the case of the NYC model, on any simulated day, millions of agents go to work/school and interact with each other in one or more of the above settings and may spread the disease. Here, we focus on testing strategies targeted at commuters and public transportation users. Those who commute via subway or ride the subway to community activities are randomly tested at subway stations if there is a testing site in that station. Each testing site is allocated a *capacity* in terms of the maximum number of daily tests that they can perform. Those who test positive will be quarantined for a user-specified number of days.

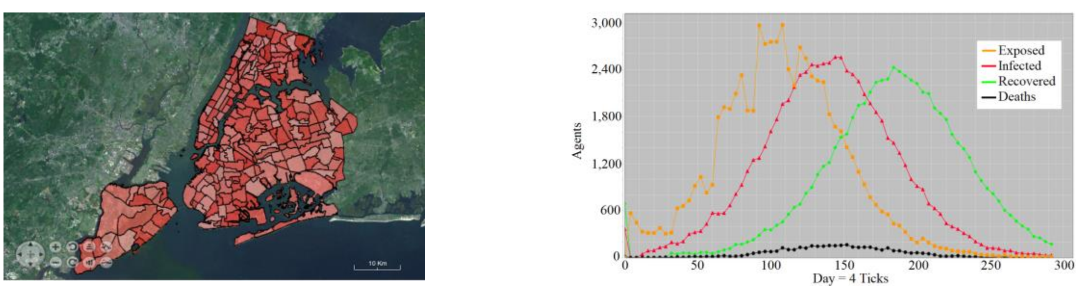
3 EXPERIMENTS

We perform multiple sets of experiments using the model calibrated for NYC and Covid-19. The calibrated model allows us to investigate a wide range of research questions including but not limited to:

- How should we prioritize NYC census tracts and subway stations for allocation of testing sites?
- How does the timing of school, workplace, and university closures affect the disease spread?
- Compare the effectiveness of random testing and quarantine versus other control strategies.

4 OUTPUT

Figure 1 shows the interactive plots of daily and cumulative infections, deaths, hospital bed usage, and other output data. The heatmap can be generated for any city as long as the shapefiles for its subregions are provided. The tool also generates spreadsheet output files of detailed replication data for output analysis.



(a) Percent infected per census tract in NYC. The darker the red, the more impacted the census tract.

(b) Daily exposure (orange), infection (red), death (black), and recovered (green) for a given simulation.

Figure 1: Interactive output plots generated by the agent-based model of New York City.

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