Review Paper 2

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1 A Network-Based Stochastic Epidemic Simulator Controlling COVID-19 with Region-Specific Policies

This paper presents an open-source stochastic epidemic simulator, calibrated with extant epidemic experience of COVID-19. The simulator incorporates information ranging from population demographics and mobility data to health care resource capacity, by region, with interactive controls of system variables to allow dynamic and interactive modeling of events. The simulator can be generalized to model the propagation of any disease, in any territory, but for this experiment was customized to model the spread of COVID-19 in the Republic of Kazakhstan, and estimate outcomes of policy options to inform deliberations on governmental interdiction policies.

Here a network-based stochastic epidemic simulator is developed and implemented which models cities and regions as nodes in a graph, and the edges between nodes representing transit links of roads, railways, and air travel routes to model the mobility of inhabitants amongst cities. The simulator includes population demographics along with health care system capacity, in particular, the intensive care unit (ICU) availability, which serves as a negative impact multiplier when the number of ICU beds is exceeded. The simulator runs a compartmental Susceptible-Exposed-Infectious-Recovered (SEIR) model, such that individuals can cycle through the four stages based on state transition probabilities. These probabilities are based on parameters such as the susceptible-to-exposed transition constant and the mortality rate, which can be influenced by age, gender, genetic profile, and health status. The simulator is labeled under certain functions such as Recovered, Susceptible, Exposed, Infected.

The simulator consists of a Stochastic Epidemic Simulator for Single Nodes. The SEIR model for a single node consists of four superstates (Susceptible (Ss), Exposed (Es), Infected (Is) and Recovered (Rs)). Again a network model in the epidemiological context is also created which is the representation of a country as a graph of interconnected nodes, where an individual node represents an administrative unit of the country, such as a city or region, taking into account their respective population demographics and health care capacities. The simulator was implemented in the Python programming language. The simulator incorporates interactive controls of state transition probabilities and modification of environmental factors such as health care capacity and mobility amongst regions. The interactive controls enable the dynamic introduction of events and the testing of policy options that allow the evaluation of alternative scenarios and projection of their potential impact over time, at both the national and regional levels.

In order to test the capability of our simulator and fine tune its parameters, The paper focused on the simulation of the Lombardy region in Italy. It is observed that the epidemic reaches a peak around 26 March 2020 when the total number of infected individuals is 67,850. If we look at the reported data, new daily confirmed cases increased significantly starting from 19 March 2020. To visualize the data a Graphic User Interface is also created. The simulator was then used to evaluate a range of scenarios with the goal of minimizing strain on the health care system while reducing negative social and economic impact by seeking a balance between containment of disease spread and the imposition of less stringent social controls on a localized basis. The projections of the simulator suggest that going forward, it will be necessary to maintain some level of social controls guided by a comprehensive testing regimen so as to constrain propagation while minimizing social and economic impact,until "herd" immunity is gradually achieved.