TJHSST Computer Systems Lab Senior Research Project
Simulation of the Spread of a Virus Throughout Interacting Populations with Varying Degrees and Methods of Vaccination
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Abstract

This project is designed to expand upon the common agent-based simulation of a virus infecting a very generic population. Factors such as multiple populations, different forms of transportation, and social interactions will be accounted for. Different maps with different types of pseudo-random populations will be created and different types of existing and fictional viruses will be simulated. Once working models are finished, the effects of vaccinating parts of the population can be modeled to determine the most effective methods and minimum percentages of vaccination needed to stop a viruses spread.

Keywords: herd immunity - type of immunity that occurs when the vaccination of a portion of the population (or herd) provides protection to unprotected individuals

basic reproduction number (R0)- the mean number of secondary cases a typical single infected case will cause in a population with no immunity to the disease in the absence of interventions to control the infection

1 Introduction - Elaboration on the problem statement, purpose, and project scope

1.1 Scope of Study

Because this project will be solely agent-based instead of incorporating system dynamics, the scope of the simulation will be limited by the processing power of the computer. There is also a limit to how detailed each agent can be. The ideal simulation would have incorporate the unique nature of each individual, but this is obviously impractical, so there will be classes of people to simulate different things like people who travel, people who work, etc. One important feature that will have to be included is hospitals because of their significant influence on the spread of disease. The variables for vaccination will include effectiveness, chance of causing the infection itself, percentages of the population vaccinated, and perhaps even some form of trace vaccination.

1.2 Expected results

This project is an attempt to determine effective methods of vaccinating a population, considering the factors of the type of population and what virus is infecting it. Different methods of vaccination will be used to see if vaccinating certain parts of the population makes a difference, what the herd immunity is, and if how extensive trace vaccinations need to be in order to be effective.

In the process of programming this simulation, I hope to learn about the spread of viruses among populations and how to model not only this spread, but the movements and interactions within basic human populations over the span of several days to weeks.

1.3 Type of research

Because of the nature of this project, it will be for the most part pure applied research, because it will attempt to apply current knowledge of viruses and vaccination to determine efficient methods of vaccination different populations. There is some use-inspired basic research, as viruses that have not been modeled can theoretically be used in this program.

2 Background and review of current literature and research

Virus simulation is by no means a new technology or study, and thus material on the subject is plentiful. Using vaccination is also a popular model to simulate, and in one paper by Bret D. Elderd, Vanja M. Dukic, and Greg Dwyer the differences in efficiency between trace vaccination and mass vaccination were studied. Other papers describe the mathematics behind various models and the variables used, such as R0 or Pr for probability of recovery. While much of this research focuses on system dynamics, it still has material covering agent-based modeling. The article on spatial simulation gives great insight into how to approach the modeling of an environment as it factors in locations such as schools, dorms, homes, work places, and hospitals, much like I intend my own simulation to use. The MIT paper compares agent-based mods to differential equation models to determine the advantages and disadvantages of both, and how they can be combined to reduce the inaccuracy inherit in both.

3 Procedures and Methodology

In order to create this simulation, my plan is to start off with a basic agent-based model, showing an extremely simple population with random movement, with basic mass vaccination and virus spread. I will use this as a stepping stone to implement more advanced modeling. Resources I will need are primarily limited to research papers already written and calculated values relating to different viruses.

Visuals of my project will include charts showing the frequency of people sick, deaths, people vaccinated, people recovered, etc. as well as maps that show incremental snapshots of the viruses spread.

The error analysis will be somewhat limited, but will primarily consist of comparisons to real world epidemics and the results of models by other researchers and scientists.

At a minimum, in its final form, my simulation should be able to model small sections of modern real-life populations as well as past populations, such as medieval villages. It should be able to track to an extent the interaction of different populations and how that affects the spread of a virus. Simulating vaccinations by the "trace" method is of a lower priority than mass vaccination, but will still be programmed to some degree.

4 Expected Results

Expectations for my program include working models of past epidemics and the capability to models possible future epidemics to a fair degree of accuracy. This type of model is especially useful in today's world, where the threat of bio-terror attacks is a real fear, and precautions must be made to react to such an event.