

Efficient Disease Control Responses

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Team 23:
Bloomfield High School

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Executive Summary

In today's world, it is not uncommon for citizens of the United States to feel unsafe. The predominant catalyst of these feelings of fear and uncertainty is terrorism. Several forms of terrorism exist, but the form our team focused on was that of biological terrorism. Biological terrorists release viruses, bacteria, or other germs to cause illness or death in people, animals, or plants. In order to prevent the spread of these biological agents, our country must be prepared to contain or eliminate them as swiftly as possible.

The thought of the release of a deadly pathogen that is odorless, colorless, and tasteless is one that reinforces the necessity of being prepared to handle such a situation. The CDC (Center for Disease Control) is the government agency responsible for this preparation. It is here that our group found the Bubonic Plague on a list of possible agents that could be used by bioterrorists. The Bubonic pathogen is a promising candidate for use by bioterrorists because it can be easily transmitted by aerosols in a very deadly form that then can spread from person to person. Our entire project is based on the hypothetical situation that this pathogen has been released within a given population, the CDC has acquired a cure for it, and that the U.S. Military is prepared to "sanitize" the vicinity if the disease is not eliminated within a specific timeframe.

Our team has prepared a model using Star Logo TNG that simulates the spread of the infectious, airborne agent (*Yersinia pestis*) throughout a population. The model uses simple collision codes to represent the transmission and extermination of the disease. By using this model, we are able to determine how many CDC "operatives" are needed in order to contain and eliminate the disease from a population within a specific window of time. Preparation is paramount; this model provides a basis for this preparation.

Our group tossed around research topics for months preceding the expo to minimal avail. After we had found one that seemed to be somewhat promising, we took a step back and began to question the potential real-world application of our proposed model. We found that our original topic was lacking in this regard, and decided that our finished model must have some type of real-world application. This change in perspective, creating a model that has some value as opposed to creating a model that merely provides a visual representation for data that already exists, is what led our group to study the transmission of airborne diseases and their relation to bioterrorism.

Before we could begin to formulate a hypothetical scenario, our team had to do extensive research in order to obtain the necessary background information. Our research focused on the nature and transmission of the bubonic virus and bioterrorism. The Black Plague, or Bubonic Plague, is an infection of rodents caused by *Yersinia pestis* and is accidentally transmitted to humans by the bite of infected fleas. It was responsible for the death of one-third of the world's population during the Middle Ages. However, the pathogen that causes this disease can be transmitted by aerosols in a deadly airborne form.

Biological terrorists release viruses, bacteria, or other germs to cause illness or death in people, animals, or plants. In September and October of 2001, several cases of the anthrax infection were recorded in the United States after several unsuspecting victims opened letters containing the virus. This was a well-publicized act of bioterrorism which motivated efforts to define bio-defense and bio-security. In light of a bioterrorism attack, the CDC rates the risk of the outbreak by assigning it to one of the following three categories: A, B, or C, A of which is the most dangerous. Only agents that pose the highest risk to the public and national security, such as the bubonic plague, are considered category A, or of the highest priority.

Category A agents can:

- be easily spread or transmitted from person to person
- result in high death rates and have the potential for major public health impact
- cause public panic and social disruption

As aforementioned, our model relies on a hypothetical scenario that includes all of the following:

- A large amount of the airborne *Yersinia pestis* virus (bubonic plague) is released by a group of bioterrorists.
- The virus is released by aerosols inside of a shopping mall and swiftly spreads into the streets soon thereafter.
- To impede the spread of the disease, the CDC (Center for Disease Control) decides that they will initiate large-scale quarantine.
- The CDC decides to send teams with newly developed antidotes into the infected area.
- If the disease is not exterminated within a specific allotment of time, the U.S. Military is prepared to “sanitize” the infected populous using whatever means necessary.

The Problem: How many CDC operatives (antidotes) are needed in order to completely extinguish the disease within a given amount of time? Which patters of personnel deployment facilitate the extermination of the disease?

It is this hypothetical that gave rise to the conception of the model itself. After the scenario was created, our group sat down and discussed exactly what we wanted the program to model. We designed a plan and drafted specific time frames in which each stage of the model would be completed. Once a plan was developed, our programmer began with a basic TNG model of an epidemic and modified to fit our specific needs.

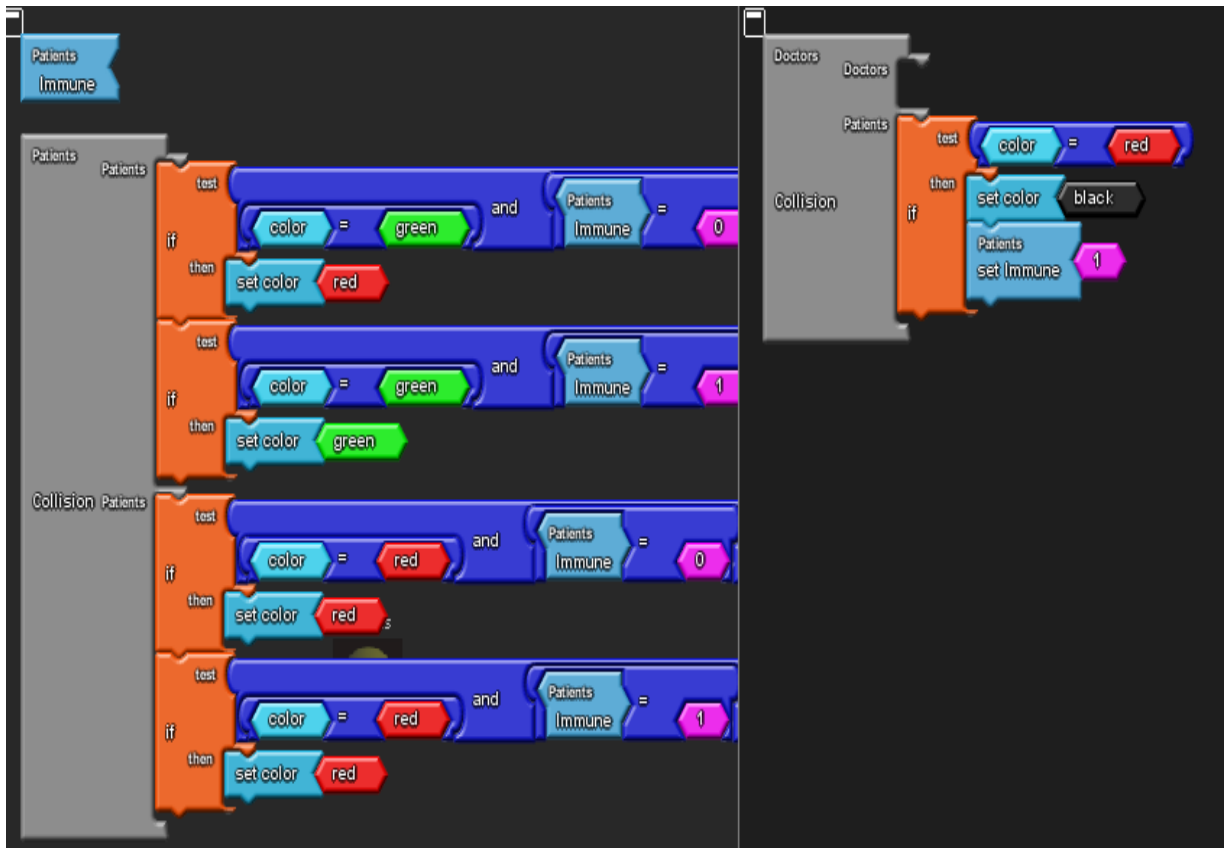
Since neither member of our team has any extensive knowledge as to how to manipulate TNG, our model is fairly simplistic. Much of the knowledge we have obtained has come from analyzing other epidemic models. Our basic setup consists of the creation of two breeds: “patients” and “doctors”. “Patients” are randomly designated to be either green, indicating their health, and red, which indicates one who has been infected. The number of “Doctors”, indicated by a blue color, is determined by a slider that has been incorporated into the model. In order to interpret the results of the simulation, we have also included a line graph in the setup. A screen shot of our basic setup is provided on the following page.

The image shows a Scratch script for a simulation. The script is organized into several sections:

- Steup (Step):** A large red block containing:
 - clear everyone** (red block)
 - create Patients:** A red block with a **num** field set to **1000** and a **do** loop containing:
 - set shape** (blue block) with a yellow sphere icon.
 - set color** (green block) set to **green**.
 - if** (orange block) with a **bool** field: **random** (500) **<** **100**.
 - then** (blue block) with a **Patients** field: **set immune** (0) (purple block).
 - set color** (green block) set to **green**.
 - if** (orange block) with a **bool** field: **random** (500) **<** **100**.
 - then** (blue block) **set color** (red block) set to **red**.
 - scatter Patients** (red block)
 - create Doctors:** A red block with a **num** field set to **Setup Doctors** (purple block) and a **do** loop containing:
 - set shape** (blue block) with a yellow sphere icon.
 - set color** (blue block) set to **blue**.
 - scatter Doctors** (red block)
- Clear:** A red block with **clear everyone** (red block).
- slider:** A red block with a **Setup Doctors** (purple block) field.
- line graph:** A red block with four **count everyone with** (purple block) fields:
 - color** (blue block) = **green** (green block)
 - color** (blue block) = **red** (red block)
 - color** (blue block) = **blue** (blue block)
 - color** (blue block) = **black** (black block)

Labels **Steup** and **Scup** are visible on the left and right sides of the script area, respectively.

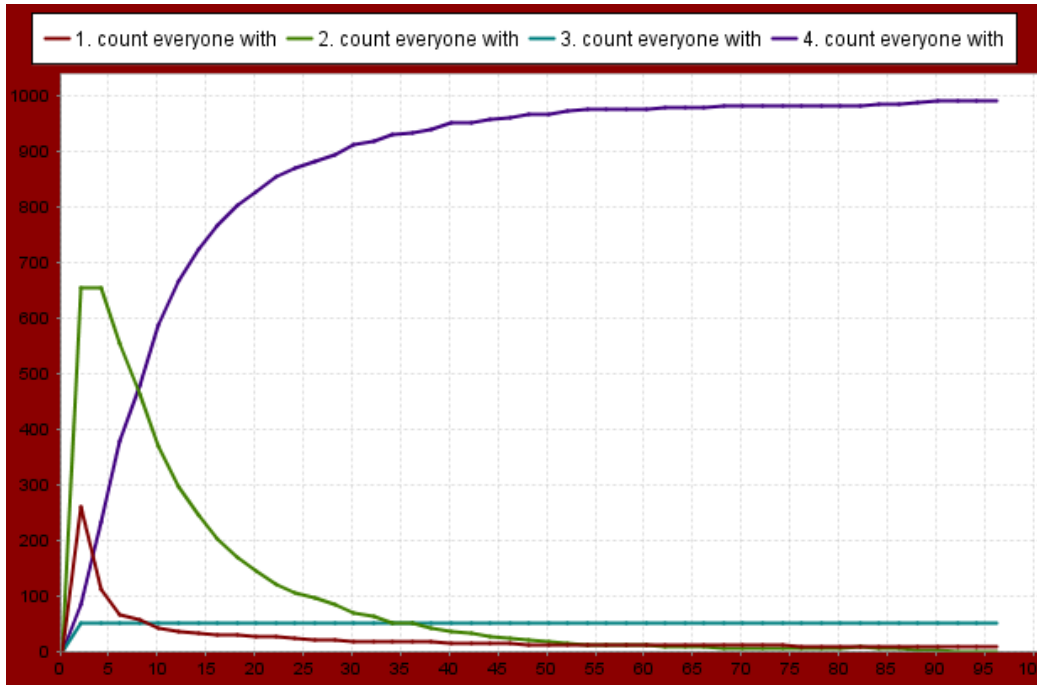
The most important part of the model is the commands given when an agent collides with an agent of a different color. When an infected agent, represented by a red color, comes collides with a healthy citizen, represented by a green color, the healthy citizen turns red. When a doctor, represented by a blue color, comes in contact with an infected agent, then the infect agent turns black. Nothing happens if healthy citizens or cured patients, represented by black, collide. Below is a screen shot of our collision setup:



Finally, we included a feature that monitors the number of those infected and cured. This feature enables us to better analyze the data. Below is a screen shot of the monitor code:



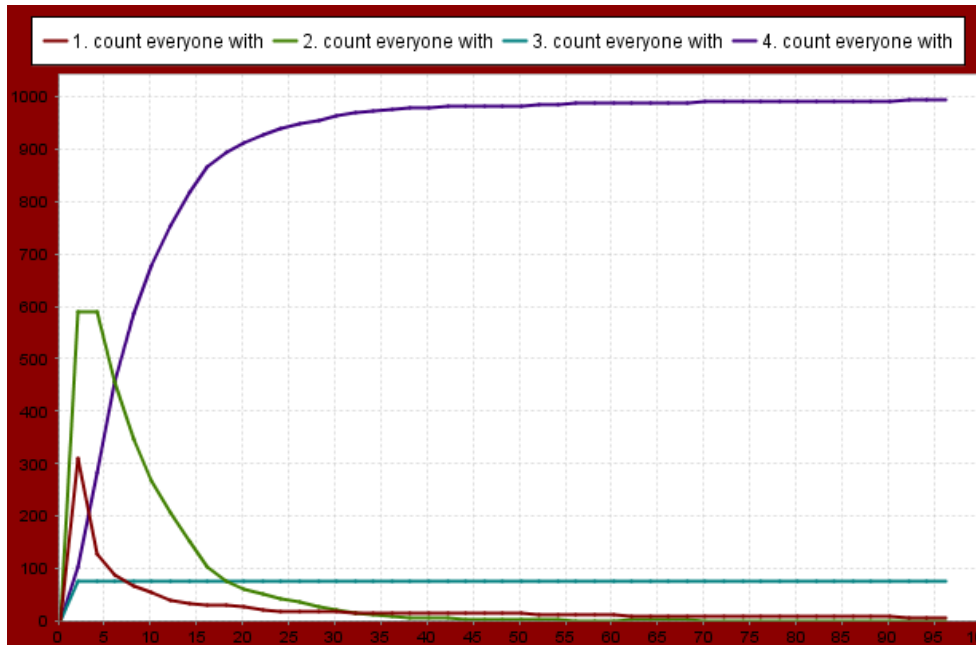
The results from this simulation are derived from analyzing the graph feature.



The graph above is based on the number of doctors being exactly 50. The turquoise, blue, red, and green lines represent the number of doctors, those who are infected, those who have been cured, and those who have remained healthy, respectively. The x-axis represents the amount of time that has gone by, measured in minutes. The y-axis represents the number of each agent, ranging from 0-1000. The turquoise line remains level because the number of doctors is a constant. The red line exponentially increases at first since infected agents can easily collide with healthy agents, but sharply decreases as soon as the number of healthy agents decreases. It then begins to slope down in a shallow curvature until it is completely eliminated at 95 minutes. The blue line steadily increases as more infected agents are being cured by doctors. The number of healthy, uninfected agents drops in congruence with that of the infected agents.

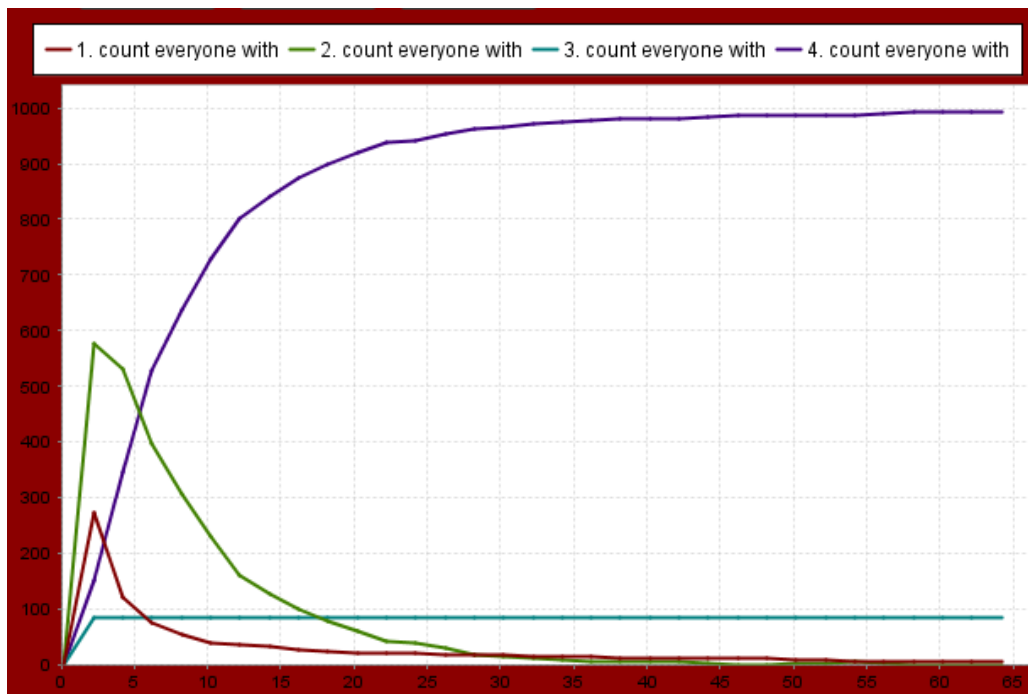
From this information, our group has concluded 50 doctors aren't enough to contain and exterminate the disease within the given time frame, which in this scenario is 60 minutes.

We then decided to raise the number of doctors to 75 and compare the results. A graph of the results is provided below.



Once again, the disease wasn't eliminated within the given time limit.

The following is a graph of the simulation using 85 doctors:



Finally, success! The disease was eliminated in 55 minutes, which left 5 minutes to spare.

After analyzing our results, our group has found that in this specific, hypothetical scenario it takes 85 doctors to eliminate a disease from a population of 1,000 in an hour or less. From this information, we can create proportions in order to determine the amount of doctors needed in order to eliminate this particular disease from any population size. For example, if the population size was 20,000, we could figure out how many doctors were needed by setting up the following basic proportion:

The image shows handwritten mathematical work on lined paper. A vertical red line is on the left side. The work consists of three lines of equations:

$$\frac{85}{1,000} = \frac{x}{20,000}$$
$$\frac{1,000x}{1,000} = \frac{1,700,000}{1,000}$$
$$x = 1,700$$

*Our most significant achievement lies in this ability to figure out how many “doctors” are needed based on a given population.

Our present model overall is fairly basic, but as time progresses, we will expand on our ideas and hopefully develop a program with a more accurate real-world application. When our group presented our model to affiliates at San Juan College, they provided us with several recommendations for improvements in accuracy and applicability. These recommendations included the following: determine an incubation period for the bubonic plague and incorporate it into the model, research nuclear fallout patterns that might be used in order to make our model more accurate, consider the presence of wind, and consider the difference between the disease being released in rural and urban areas. We plan to experiment with different deployment numbers and patterns, as well as redevelop our terrain. All we need is more time to broaden the scope of our project!

We would like to provide a special thanks to John Gonzales and Janet Penevlope for willingness to work with those who don't know much about supercomputing and the language associated with it.

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Thank you for allowing our team to participate in this year's challenge!