# Smallpox Outbreak Modeling in Python

Joe Fetsch
Computer Systems Lab 2009-2010

## Abstract

This project is intended to model a martyr-type scenario in which a small terrorist groups infiltrate a city after infecting themselves with Variola Major; they attack hospitals first, passing as flu sufferers until the virus becomes contagious. After panic begins to spread, as the population realizes that they would have to avoid medical facilities even if they become infected, the remaining faction infiltrates the city, possibly in health control uniforms, fostering distrust of the government, spreading the virus further. With the mass panic and disease spreading, the city shuts down. Nobody is allowed in or out, effectively quarantining the city. Residents panic and remain at home in fear of infection, at which point the city stops functioning completely, and chaos runs free as infections spread and disease control units are helpless to intervene due to the quarantine and the population's general panic and instilled fear of health officials, causing them to refuse to cooperate.

## Background and Introduction

Smallpox, also Variola Major, is a fast-spreading disease with a 100% susceptibility rate in humans who have not been immunized in the past 10 years. The only populations recently immunized are military or health control workers.

Smallpox has a 35-40% fatality rate and spreads like wildfire because of the 2 week incubation period in which no symptoms are shown from the infected person: as they travel around, moving to uninfected cities or healthy sections of a population, the sudden outbreak creates many more victims for the disease.

## Discussion

Python is used in the final project in which a simulation of the scenario described above will be run. A full military quarantine on the city in which the initial infection takes place, where all agents can no longer travel, reducing the risk of infection of other agents nearby to zero, or the creation of a vaccine, produced, and distributed, where agents become immune and the chances of an agent recovering from infection, if administered soon after infection, are high, are two possible outcomes of the simulation. Data from simulations is used to compare an effective method of control (quarantine) to a moral high ground (vaccination).

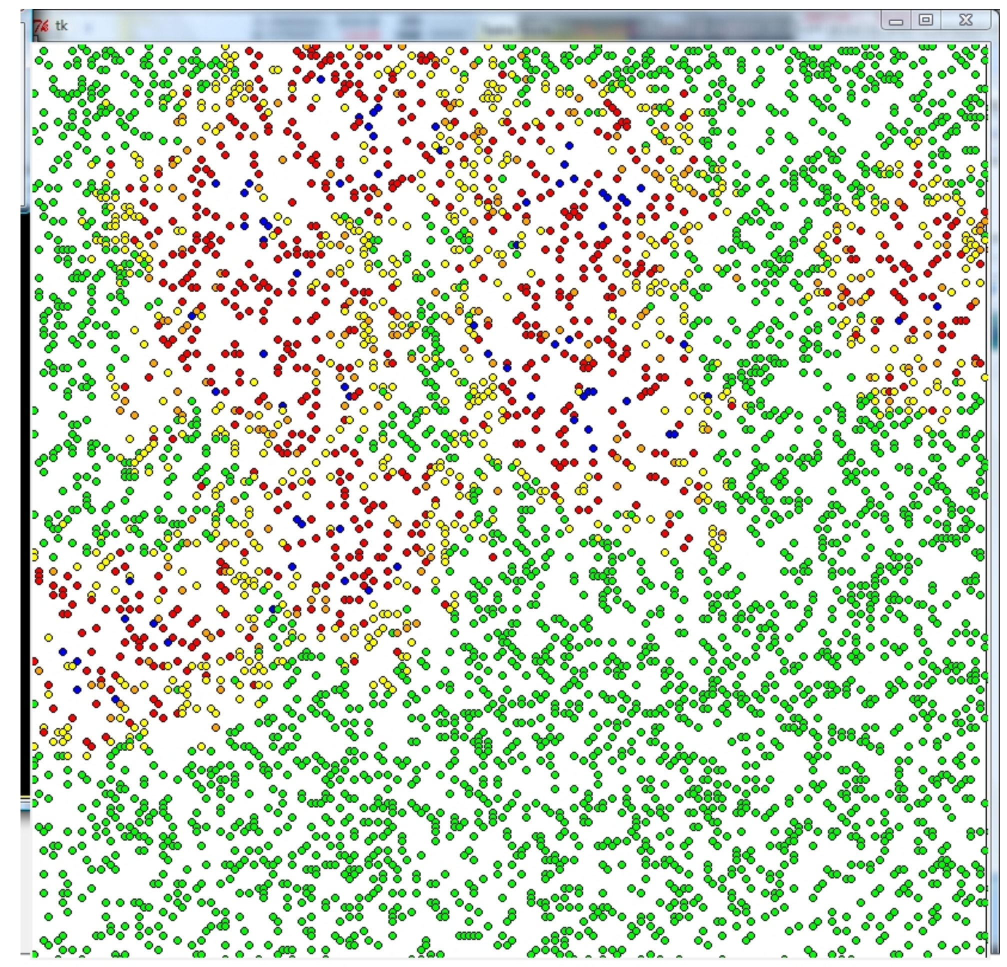

Figure 1: A typical display of the world where green agents are healthy, red are infected, orange are in the prodromal phase, blue are immune, and yellow agents are carriers of the smallpox virus – this image is from about 2 and a half months after the first stages of the attack.

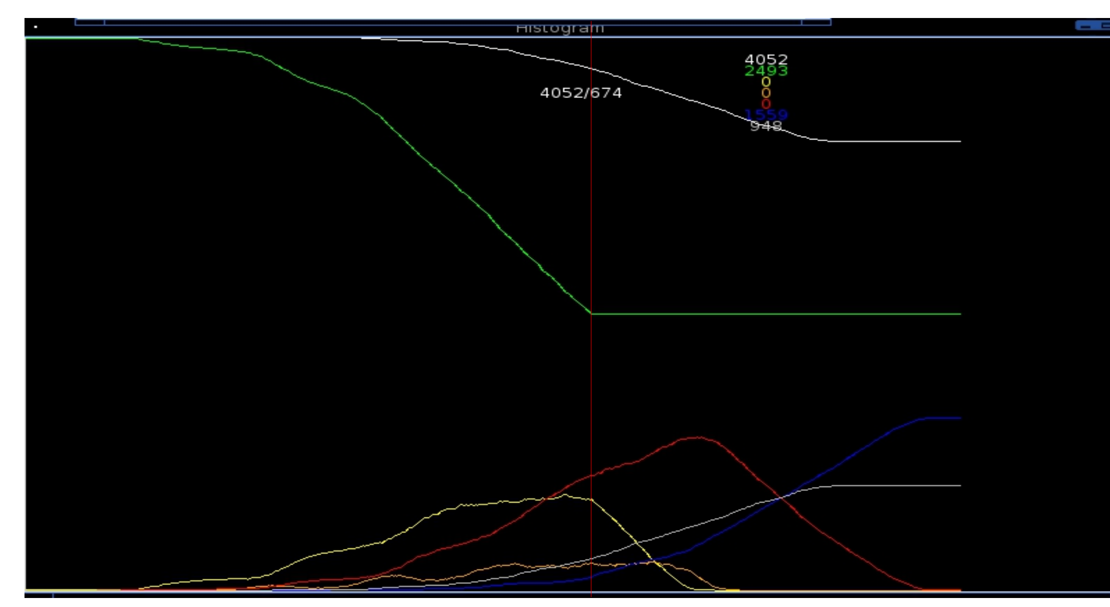

Figure 2: a visual representation of the population over time using the color scheme described above. Time span graphed is about 4 months with quarantine implemented at around 2 months.

## Results and Conclusions

Figures 1 and 2 show sample runs of the program:

Figure 1 is a visual depiction of the social interactions between the agents: the closer two agents are to each other, the more time the two people represented would spend together. No quarantine or vaccination has taken place yet.

In this particular scenario, a quarantine would be very possible, and, if a quarantine was implemented, would likely have a death toll of around 750, with about 2000 people having been infected out of 5000: in a larger scenario, in which the infected travel to other areas, the expected fatality rate would be around 15% and the expected infection rate after two and a half weeks would be about 40%. In a vaccine situation, the fatality rate would be around 600 with 2000 people being infected: only a 12% fatality rate compared to the quarantine scenario's 15%.

In Figure 2, a quarantine has taken place. The population of the city has gone from 5000, the initial value, to 4052; a fatality rate of 20%. However, the population in this situation was quarantined after two months of the simulation, while the rate of infection was still increasing, which would lead to many more cases of smallpox and many more fatalities. Throughout the simulation, about half of the agents became infected, which raises the relative fatality rate to slightly less than 40%.

After the quarantine was implemented, the number of healthy people leveled off at 2495, as can be seen in the graph, while, at the same time, the number of carriers no longer increases after that time, immediately after the number of infected people becomes greater than the number of carriers in the simulated world. From the graph, it is possible to notice the increases in the number of carriers, infected agents, and immune agents as they progress, defining the generations of infection. After the last generation becomes infected, defined by the time of quarantine, all of the values drop off after the generation progresses to the next stage of disease.

Running multiple simulations for several lengths of program, the expected results of the simulation when the quarantine and vaccination are implemented are found: A quarantine is much easier to implement than creating and distributing a vaccine to a new disease, so the times of quarantine are earlier than those of vaccine distribution.

The quarantine simulation (Figure 4) tends to simply end the simulation, and can easily be calculated without the simulation: on average, the number of people who have been infected *0.362 is a good estimate of the fatality rate of the simulation.

The vaccination scenario (Figure 5), on the other hand, varies with the time at which the vaccination began with regard to the start of the attack. Because those who have recently been infected are likely to recover, the fatality rate of a vaccine scenario is lower than that of the quarantine scenario IF they occur at the same time after the attack: in the situation in Figure 1, the difference would be 12% fatality rate to a 15% fatality rate, which is a difference of about 150 lives. In order to have comparable fatality rates after two months, the quarantine must take place 6 days before the vaccine would be introduced in the scenario. However, a quarantine is much easier to implement and vaccine development is not very predictable, so the quarantine may still have the best dependability and the best results on the fatality rate in a real world situation.

This must, however, be compared to the moral dilemma of taking away the rights of the citizens who, while they may be infected, do not want to be controlled and refuse to forfeit their rights: the vaccination holds the moral ground, but the quarantine gets the job done quickly and efficiently. However, if the vaccine can be developed within 10 or so days of when the quarantine is developed, more lives will be saved from the vaccine.

This leads to questions that must be answered whenever a situation of this type arises: “What is more important, the lives of the people, or the rights of the people?” and “Can we develop a vaccine fast enough, and is it worth the risk of waiting for it?”

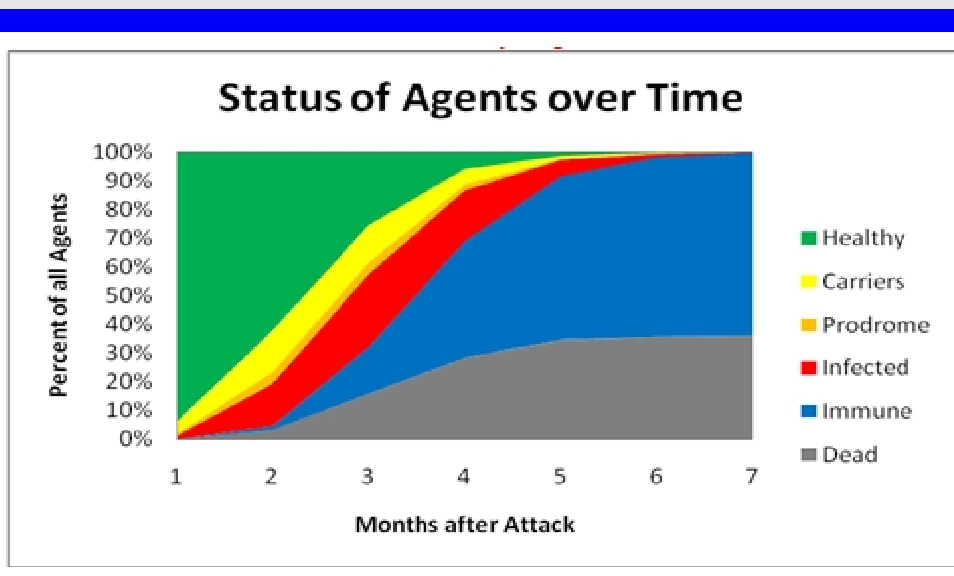


Figure 3: the above graph shows the average results of a run in which no control is taken over the population.

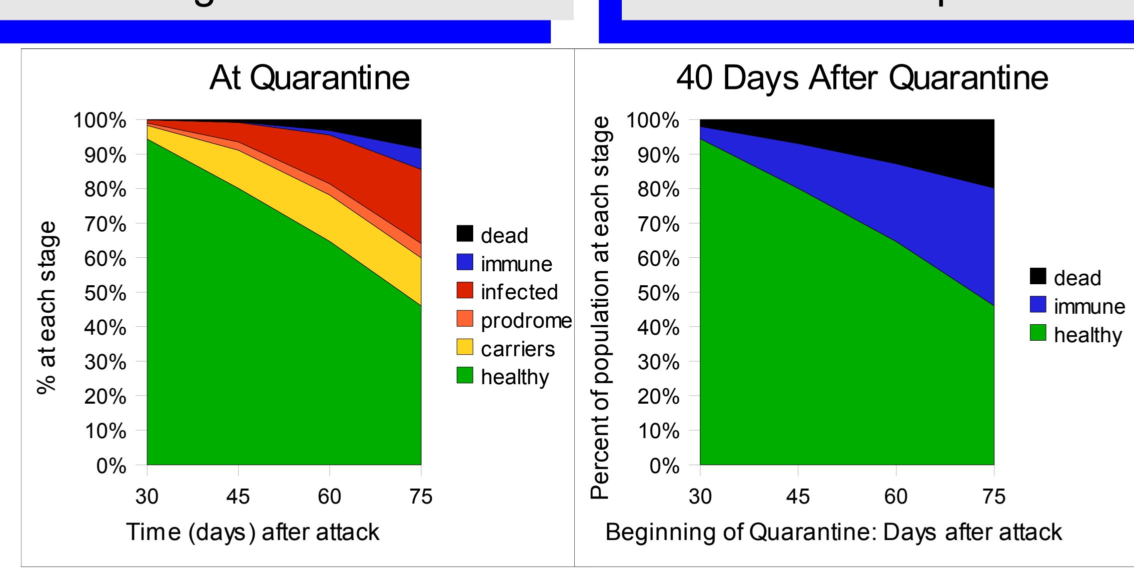


Figure 4: the above graph shows the average results of a run in which quarantine has been implemented at varying times after the initial infection, and the chart shows the fatality and infection rates of the simulation at those times.

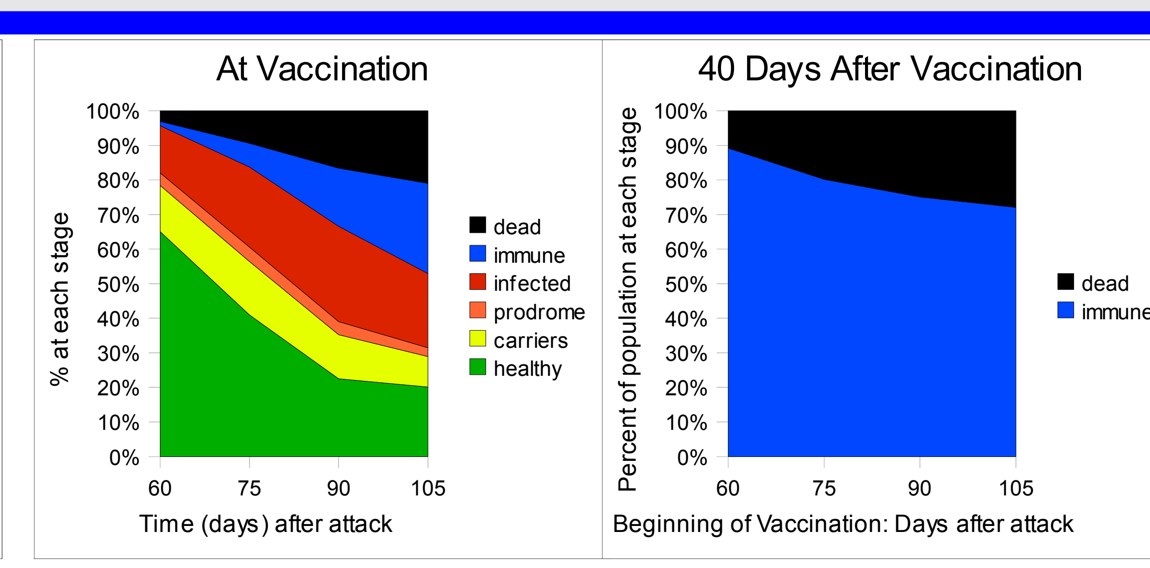


Figure 5: the above graph shows the average results of a run in which a vaccine has been implemented at varying times after the initial infection, and the chart shows the fatality and infection rates of the simulation at those times.

Fatality rates for quarantine simulations:

30 days: 102 (2%)
45 days: 350 (7%)
60 days: 643 (13%)
75 days: 992 (20%)

Infection rates for the simulations:

30 days: 279 (6%)
45 days: 995 (20%)
60 days: 1766 (35%)
75 days: 2698 (54%)

Fatality rates for vaccine simulations:

60 days: 540 (11%)
75 days: 991 (20%)
90 days: 1247 (25%)
105 days: 1396 (28%)

Infection rates for the simulations:

60 days: 1747 (35%)
75 days: 2951 (59%)
90 days: 3873 (77%)
105 days: 3991 (80%)