PHSX815_Project2:
Return of the Rakghoul Plague (based on a plague in Star Wars)

Gene Stejskal

March 13, 2023

1 Introduction

The Rakghoul Plague has returned! The last time the Rakghoul Plague appeared, it was ravaging the underworld of Taris, and threatened to reach the surface of the planet, where the majority of the citizens reside. Our plague scientists, through collecting and modeling infection rate data for that plague, and through the use of hypothesis testing and distribution modeling, we were able to model and eventually create a anti-plague serum, which was effective at slowing down and even curing the plague.

We thought the plague went extinct, but it has evolved and resurfaced. The rakghoul plague bacteria has become immune to the original rakghoul serum. The bacteria's biology has become more complex, making any possible serums harder to replicate and model now.

One of our top plague analysts has come up with a more complex distribution to model the plague spread using Monte Carlo Sampling. From this, we are able to develop and model two new trial serums (serum 1 and 2), which we can compare against our collected/modeled plague data, to develop a new plague cure.

This report is organized as follows: Sec. 2 explains the differences in several trial serums my team is working on, and a description of the computer simulation developed to simulate these possibilities is provided in Sec. 3, with an analysis of the outputs included in Sec. 4. Finally, conclusions are presented in Sec. 5.

2 Discussion of Possible Trial Serums and Infection Rate Simulation

As mentioned above, the goal of this project is to simulate plague infection rate after introducing two different anti-plague serums into the population, in order them to compare to the raw plague infection data. The evolved bacteria is structurally more complex, and in lab observation, is shown to have a much greater immunity to a variety of treatments, and more endurance in a greater variety of environments. The old serum is having nearly zero effect on the bacteria, making a need for a new serum paramount.

Despite the hardships, our team has come up with two new trial serums, which have shown promise in small scale observation. It is clear that to cure the plague, requires a much stronger and multi-pronged solution. The first of our two serums, works through the use of a biological-nanodroid technology. By implanting these droids with the plague's DNA marker, the nanodroids can search out and target plague bacteria, and once found will infect the bacteria and begin to unravel the bacterial DNA, effectively destroying the cell.

The second of the two serums works by altering the body's chemistry slightly in a way which creates a toxic environment for the bacteria, which weakens the bacteria cells, allowing the body's natural

immune system to more easily destroy the plague. In the following section, it is discussed how our team modeled the new plague infection rate, as well as the effects of the serums.

3 Code and Experimental Simulation

The bones of our model are very similar to the first iteration. Once again, we are using three separate codes. The first being a random class which contains all of the code used to generate the distribution. Second, there is the data generation code, which uses the random class to generate a list of data according to our chosen distribution. And, lastly, there is the analysis code, which collects and reads our data, and displays it in histogram form for analysis.

The previous version of the plague was best described by a Log-normal distribution, which was chosen because the log-normal distribution is often used to model epidemiological data such as virus spread. The "log-normal" distribution, X, takes a random variable, R, generated according to a normal distribution, and transforms it using an exponential function:

$$X = e^{\mu + R\sigma}$$

where μ and σ are parameters related to the actual mean and standard deviation of the log-normal distribution, mux and $sigx$. I, however, want the distribution to take the variables mux and $sigx$, so transformations are needed to convert from μ and σ to mux and $sigx$. These are the following:

$$\mu = \ln\left(\frac{mux^2}{\sqrt{mux^2 + sigx^2}}\right) \tag{1}$$

$$\sigma = \sqrt{\ln\left(1 + \frac{mux^2}{sigx^2}\right)} \tag{2}$$

This allows use to have our distribution $X = X(mux, sigx)$. Our new model must take into account the more complex nature of the plague. It was decided that this was best solved by having the standard deviation $sigx$ be sampled from a gamma distribution which is dependent on two new fixed variables, α and β. Here, α is a shape parameter, while β is the rate parameter; changing these affects the width and height of the distribution. The gamma distribution was chosen mainly because it has the same range, $[0, \infty)$, as the log-normal distribution, but also because it is another common distribution for epidemiological modeling. To get our total probability distribution for a given hypothesis H, which is our model for the plague infection data, we must average $P(X|mux, \alpha, \beta)$ over all the possible distributions of $sigx$ given fixed α and β:

$$P(X|H) = \int_{-\infty}^{\infty} P(X|mux, \alpha, \beta)\, dsigx = \int_{-\infty}^{\infty} P(X|mux, sigx) P(sigx|\alpha, \beta)\, dsigx \tag{3}$$

This gives us a three dimensional distribution (dependent on three fixed parameters), as opposed to our old two dimensional model; this more complex distribution allows us to model a greater variety of shapes and hypotheses.

4 Output Analysis

The code outputs a histogram of the plague infection data, which was collected (in green). It also models the infection data of a population inoculated with both serum 1 and 2 (blue and red). The

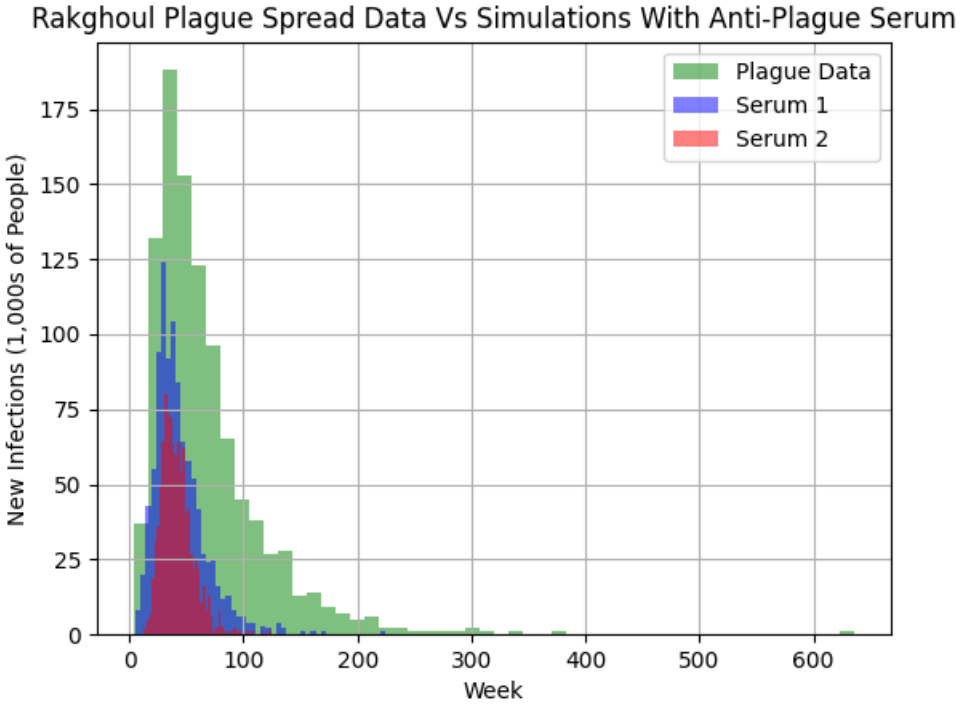

Figure 1: Histogram showing the new infection cases for the Rakghoul plague per week (green), and comparing to the infection simulations for Serum 1 and 2 (blue and red).

evolved plague, as is seen in figure 1, dies off much slower than the original plague, lasting nearly 400 weeks, with new cases still appearing at around week 650.

To gauge the effectiveness of the two serums, we are looking at the week with the greatest number of infections, the peak number of infections, and the rate at which the plague dies off. The plague infection rate data shows a peak at week 50, infecting a total of 180,000 citizens, this also shows most case are dying off around week 250, but infection continue to be documented up to around week 380, with a flare up at week 650. With serum 1, the plague infection reaches a peak of 125,000 citizens infected during week 40, and dies off much quicker at around week 170. Finally, with serum 2, the plague infection peaks at around 80,000 citizens infected, and dies off almost completely by week 100.

Based on these models, with serum 2, the population reaches a much lower peak number infection in about 4/5 of the time, and also dies off completely in around 1/4 of the time. This tells us that serum 2 will work more efficiently as a cure compared to serum 1.

5 Conclusion

To conclude, the rakghoul plague, which was infecting the citizen's of Taris, turning them into blood thirsty rakghouls, has evolved and resurfaced with a more complex and aggressive biology. The new plague bacteria is immune to our old serum, so it is imperative a new serum is developed to fight the plague. Using Monte-Carlo sampling to model a more complex distribution, the plague infection rate was modeled for the introduction of two different serums into the population. It was found that with serum 2, the peak plague infection number is much lower, having been reduced by around 55%. With serum 2, the plague also goes extinct much quicker; the extinction time is reduced by around 60% -

74%. This proves that serum 2 is an effective cure for the new rakghoul Plague.

References

[Rogan] https://github.com/crogan?tab=repositories

[Stejskal] https://github.com/Stayskul

[Singh] https://www.geeksforgeeks.org/how-to-generate-random-numbers-from-a-log-normal-distribution-in-python/

[StackOverflow] https://stackoverflow.com/questions/6871201/plot-two-histograms-on-single-chart-with-matplotlib

[Wikipedia] https://en.wikipedia.org/wiki/Log-normal_distribution#Properties

[Wikipedia] https://en.wikipedia.org/wiki/Gamma_distribution