Numerical simulations for the impact of human intervention to transmission of disease

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1 Introduction

As soon as most humans become city dwellers, a plague has been a test for the delicate system of the city. Human interventions are needed to maintain the delicate man-made system. This article will use numerical simulations to illustrate the impact of human intervention on the transmission of disease.

The program can be be found in the **Github**, the demonstration can be found in **YouTube**

2 Method

The script will initiate a list of humans with a randomly chosen neighbor with whom they are interacting on daily basis. The elements of the neighbor list can be repeated in order to mimic the frequent interaction. There is 1 human who has the disease. The disease will be transmitted via interaction with the neighbors by giving a chance of infection. The amount of neighbor and total population can be set by the user.

One is more likely to get infected if one has longer contact with infected individuals. This phenomenon can be quantified by the following equation.

$$P_{tot} = 1 - (1 - P)^n \tag{1}$$

Where P are the probability of getting infected if the one interacts with one infected individual, n is the number of infected people one interacts with daily, P_{tot} is the overall probability of one getting infected.

There is a part of the population that cannot be infected by default, which can be understood as a vaccinated group. The vaccination rate can be set by the user as well.

The baseline has the following parameter: humans interact with 20 people daily, there are 40,000 people in total, 0% of the population are vaccinated, one has 2% of the probability of getting infected. The plot of the baseline parameter is shown in Figure 1.

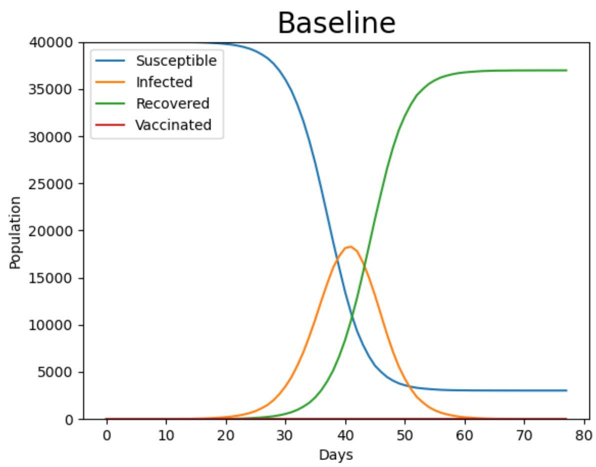

Figure 1: Simulation with the Baseline parameter: Blue curve is the the number of the susceptible population, orange curve is the the number of the Infect population, green curve is the the number of the recovered population, red curve is the the number of the vaccinated population

Figure 1 demonstrated a few interesting phenomenon. The total recovered population is less than the overall population. In other words, not everybody is infected before the disease has extincted. Such a phenomenon is related to herd immunity [1]. The Infected population has a peak for a given time in such a model. The height of the peak and the time it takes to reach the peak can be used as two important indicators for public health. The government needs to implement the human intervention in order to make the peak of the **infected lower than the capacity of the hospitals** and give **hospital enough time to react to the infection spike**. The dependence on the different parameters will be studied in the following section.

3 Parameter scan

There are a few parameters to be examined:

- Amount of people one interact with
- The chance to getting infected
- Ratio of the population that are Vaccinated

The parameter scan has been based on the baseline case: other parameters are fixed to the baseline and the scanning parameter is varied.

3.1 Human Interaction scan

As Figure 2 and 3, the number of people one interacts with has a large impact on the height of the peak and the speed of reaching the peak. Lockdown city is effective against the plague. However, as a social animal, human needs a basic level of human interaction to maintain psychological stability. Thus, one could gauge the limit of human interaction for the given conditions.

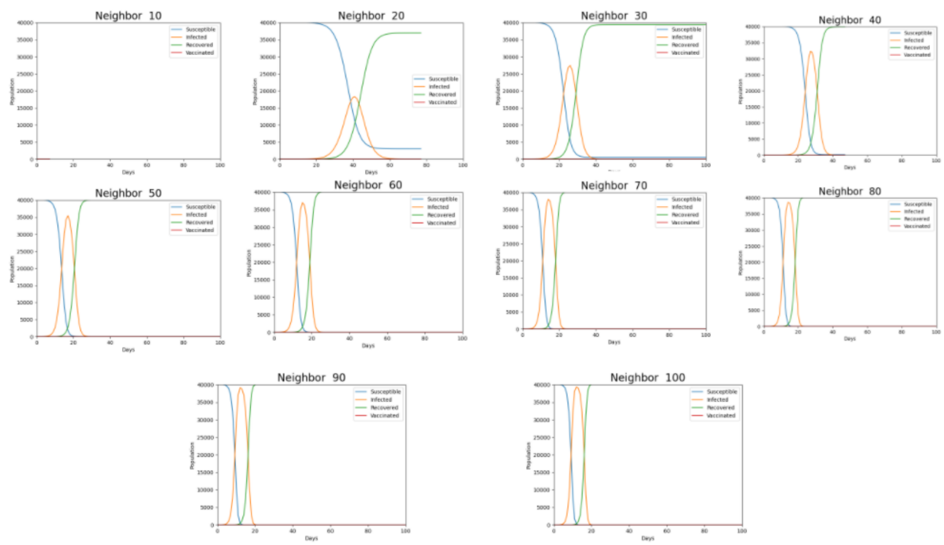

Figure 2: Human Interaction scan with 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 neighbors

3.2 Infection rate scan

As Figure 5, 6 and 7 shown, Infection can be reduce by enhanced ventilation, social distance or properly wore mask.

3.3 Vaccination rate scan

As Figure 8, 9 and 10 shown, The ratio of population that are Vaccinated can greatly influence the chance and speed of herd immunity. One can clearly see in Figure 9, vaccinate over 60% of the population will provide a speedy recovery from a plague.

4 Conclusion

This set of simulations demonstrated the impact of limiting the interaction with a human, reducing the chance of infection, and vaccination. All of them can be

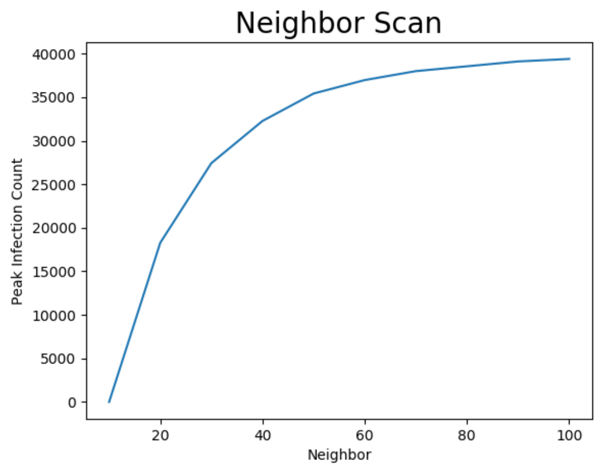

Figure 3: Number of people one interacts with VS the height of the peak

used for decision-making. But human society is not only focused on the plague. Studying the side effect of human intervention is needed in order to reduce the overall impact of the plague. The author is almost certain that strong human intervention is not needed state wide. For instance, the countryside has less human interaction, the newly infected person is introduced into the community, therefore require fewer restrictions.

In the future, the realistic model will be studied with realistic human density, age distribution, death rate. Statistical analysis on the side effect of human intervention will be performed once the comprehensive data is available.

References

[1] T.J. John and R. Samuel. Herd immunity and herd effect: new insights and definitions. 2000.

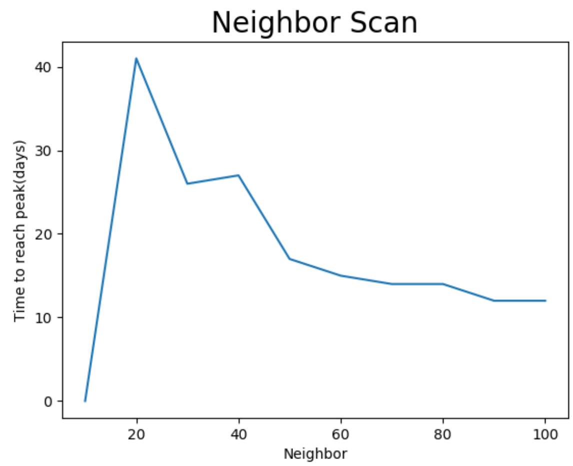

Figure 4: Number of people one interacts with VS time to reach the peak

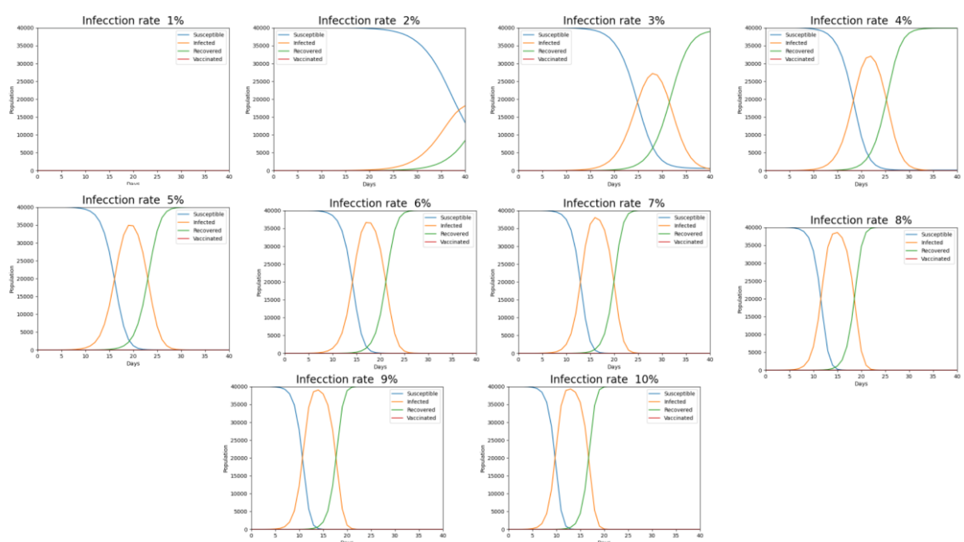

Figure 5: Infection rate scan with 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10% chance of getting infected

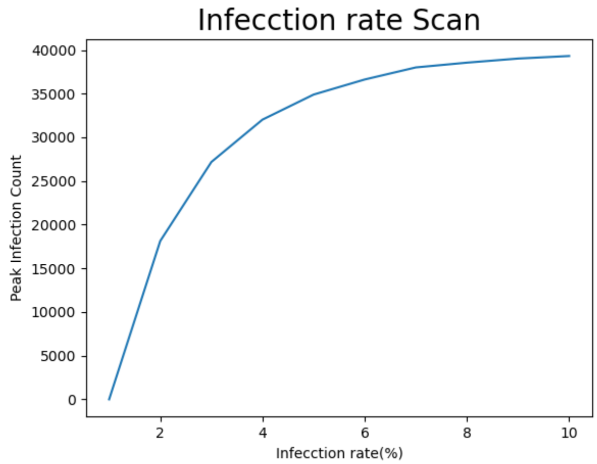

Figure 6: Chance of infection VS the height of the peak

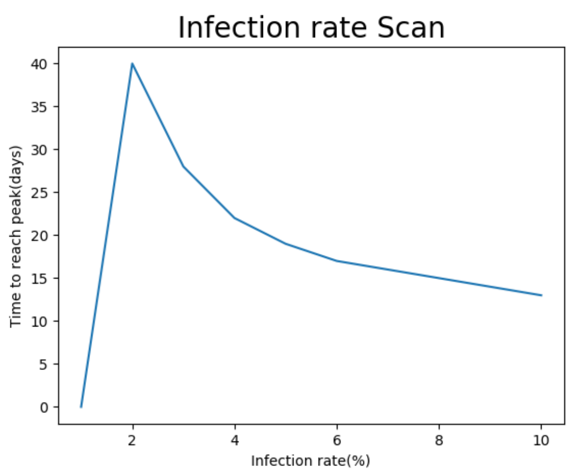

Figure 7: Chance of infection VS time to reach the peak

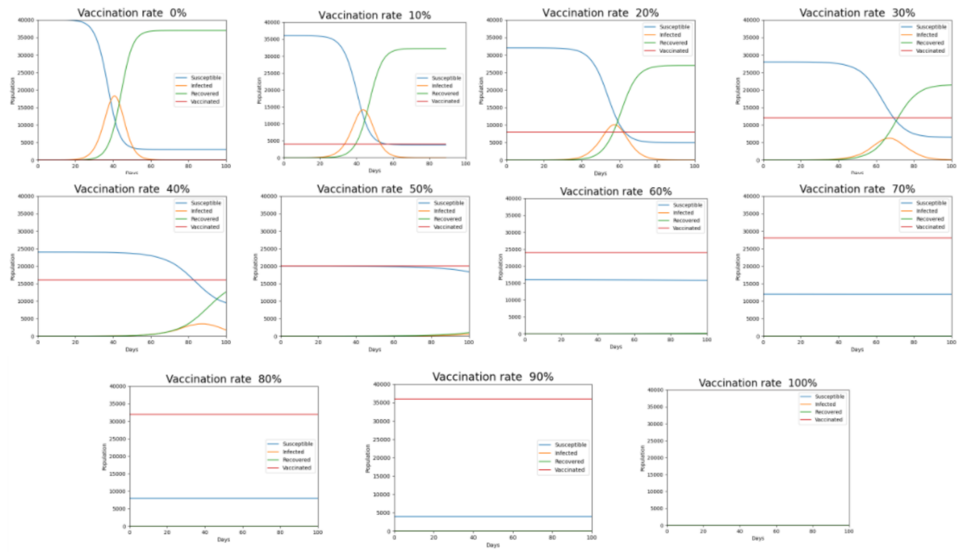

Figure 8: Vaccination rate scan with 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% of population getting vaccinated

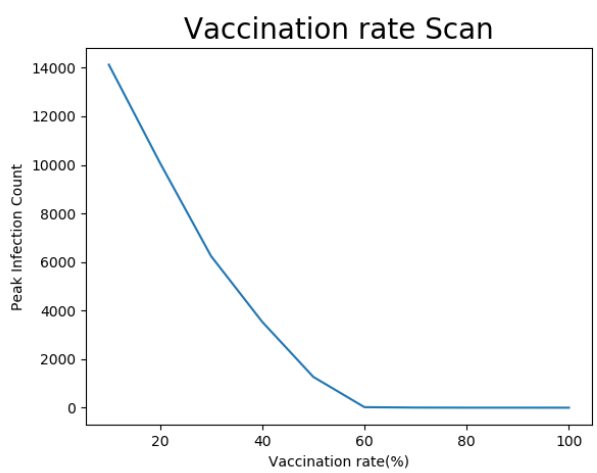

Figure 9: Vaccination rate VS the height of the peak

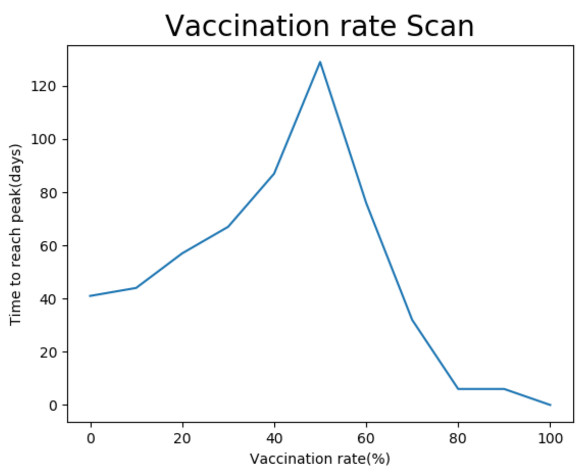

Figure 10: Vaccination rate VS time to reach the peak