Infectious Disease Simulation

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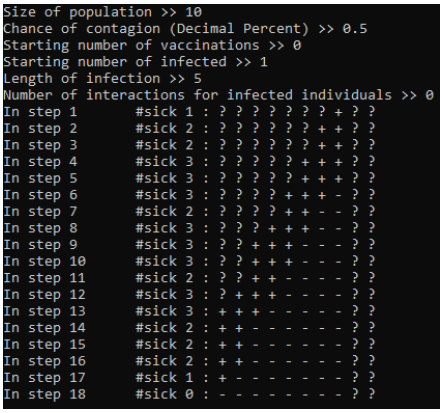
51.3. Localized Interactions with Varying Contagion

In this experiment, I performed three different tests between a small population with a disease with a high chance to spread between neighbors, a large population with a low chance to spread between neighbors, and a large population with a high chance to spread between neighbors. **Figure 1** shows that diseases with low contagion rates die out quickly and only infect a few localized individuals. On the other hand, high contagion rates have varying effects dependent on whether the population is small or large. In a small population, the contagion spreads rapidly but has a shorter lifespan as the population develops immunity. In a large population, the disease still spreads rapidly, however since interactions are mostly localized, it takes a long time for the disease to spread throughout the population.

a

b



c

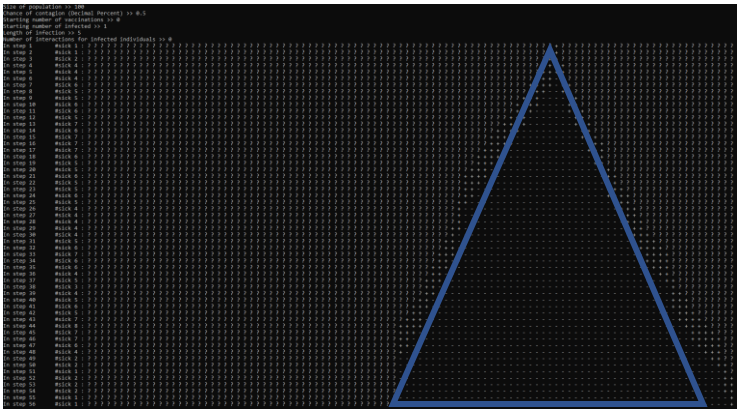


Figure 1: a) Large population with a low contagion rate (10% chance of spreading). The blue rectangle highlights the relative infected region. **b)** Small population with a high contagion rate (50% chance of spreading). **c)** Large population with a high contagion rate (50% chance of spreading). The blue triangle highlights the relative infected region.

51.4 Localized Interactions with Vaccination

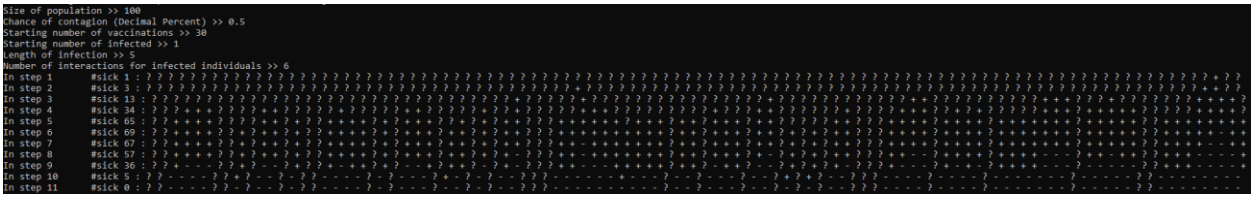
Even at low percentages of vaccination, **Figure 2** shows that with only localized interactions between neighbors, vaccination has a profound effect on the spread of the disease. This is because any interaction with a vaccinated member of the population curbs the spread of the disease any further in that direction in an almost vaccination barrier. However, this model is unrealistic because interactions between individuals is not localized between neighbors and can jump the vaccination barrier.

Figure 2: Vaccination rate of 30% in a large population with large contagion rate (50% chance of spreading). The blue rectangle highlights the relative infected region.

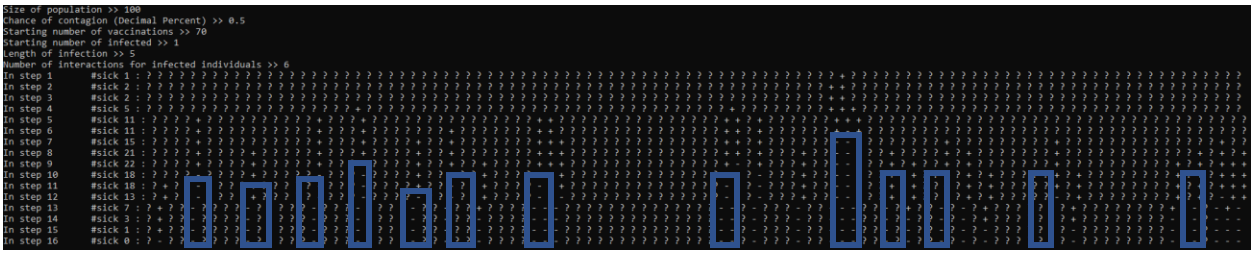
51.5.1 Delocalized Interactions with Vaccination

Upon introducing an ability within the population to interact outside of a localized region, the effectiveness of vaccination in curbing the spread of diseases became clearer. As seen in **Figure** 3, at low (30%) and moderate (70%) vaccination rates, most non-vaccinated individuals got infected with an average of 0.66 and 3.5 uninfected non-vaccinated individuals in the population, respectively. However, upon reaching high vaccination rates of 95%, it became extremely rare for non-vaccinated individuals to get infected. This demonstrates the effect of herd immunity. Only after passing a high threshold vaccination rate do non-vaccinated individuals see a significant improvement in their odds of not getting infected.

a



b



c

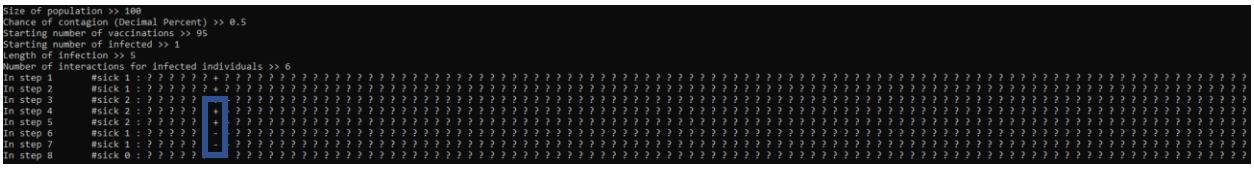


Figure 3: a) Vaccination rate of 30% in a large population with large contagion rate (50% chance of spreading). **b)** Vaccination rate of 70% in a large population with large contagion rate (50% chance of spreading). The blue rectangles indicate pockets of infected individuals. The number of non-vaccinated individuals who were infected hovered between ~3-6 which is not significant from 30% vaccination rate's ~3 uninfected. **c)** Vaccination rate of 95% in a large population with large contagion rate (50% chance of spreading).

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Population Size	Contagion Rate	Vaccination Rate	Infection Length	Interactions Per Infected	Percentage of Non-Vaccinated Who Were Not Infected
100	50%	**30%**	5	6	1.45%
100	50%	**30%**	5	6	0%
100	50%	**30%**	5	6	1.45%
100	50%	**30%**	5	6	2.90%
100	50%	**70%**	5	6	17.24%
100	50%	**70%**	5	6	0%
100	50%	**70%**	5	6	17.24%
100	50%	**70%**	5	6	13.79%
100	50%	**95%**	5	6	100%
100	50%	**95%**	5	6	100%
100	50%	**95%**	5	6	75%
100	50%	**95%**	5	6	100%

Table 1: The effect of vaccination rate on populations with delocalized interactions. The percentage of non-vaccinated individuals who were not infected does not count the originally infected individual.

As seen in **Table 1**, evaluating the percentage of non-vaccinated individuals who were not infected in a population with a variant vaccination rate gives an increase in the percentage of non-vaccinated individuals at an almost exponential rate with increasing vaccination rate.

51.5.2 Percentage of Vaccination for Herd Immunity as a Function of Contagiousness

Contagion Rate	Vaccination Rate for Complete Herd Immunity
10%	60%
15%	76%
20%	85%
25%	87%
30%	92%
35%	92%
40%	93%
50%	95%

Table 2: The effect of contagion rate on herd immunity for populations with delocalized interactions. Herd immunity is defined as having no spread of the disease past the first individual.

Plotting these values for vaccination rate over contagion rate similarly grants a logarithmic graph where the vaccination rate required for herd immunity at higher contagion rates tapers off nearing the point of complete vaccination of the entire population.