S(E)IR Model and its Application in Seasonal Flu

Shizhao Yang

Objectives

Model Analysis

1. Analyze how could the SIR model be modified to include separate compartments for dead, recovered and vaccinated populations. Write down the deterministic version of such a model and explain the new parameters.

2. Use variables from the model (S, I and R) to represent the quantity of new positive cases per day (denoted by $C(t)$).

3. Compute the replacement number rt without knowing all of the underlying model parameters, such as a form that involves only the removal rate b. Alternatively, Calculate the exponential growth rate of I for some short period of time during which an outbreak is starting.

4. Draw the phase plane of the solution space for the SIR model and SEIR model separately, using nondimensionalized population fractions $s = S/N$ and $i = I/N$.

5. Derive the peak number of infectives I_{max}, and if possible, estimate the time at which this peak occur, using the approximate solution derived in chapter 10 of Murray.

6. Show that the peak in the daily new cases $C(t)$ occurs before the peak in infections.

7. Analyze the major weaknesses of the SIR model for modeling Seasonal Flu.

Data Analysis

1. Use the Flu data download from health.data.ny.gov which includes last 12 years and analyze and compare the behavior of seasonal influenza in New York in the last 3 or 4 years.

2. Estimate the parameters a (average number of adequate contacts per person, per unit time) and b (the inverse average removal time) using **Gauss-Newton method** or **Quasi-Newton method** of the past 2 or 3 years, and use it to predict the trend of influenza this year.

3. Estimate the basic reproduction number r0 (compare this to the estimate r0 = 2.2).

4. Estimate the population fraction that needs to be immuned in order to have herd immunity

5. Compare the behavior of seasonal flu before and during the Covid-19.

6. If possible, consider including the timeseries of the vaccinated population in the model, based on your answer to Analysis question 2 above.

References

[1] H. W. Hethcote, "The mathematics of infectious diseases," *SIAM Review*, vol. 42, no. 4, pp. 599–653, 2000. [Online]. Available: https://doi.org/10.1137/S0036144500371907