SEIR Model for COVID-19 Cases on County Level

Mengyu Zhang
University of California, Los Angeles

ABSTRACT

The new type of coronavirus (COVID-19) is an acute respiratory infection caused by a coronavirus infection. Since the first case was confirmed, people's social and economic lives have been greatly disrupted. Although the governments have introduced a series of prevention to curb the spread of the epidemic, the situation around the whole world is still relatively severe.

Based on the complex network theory, an SEIR dynamic model of the COVID-19 epidemic on the county-level is established in this project. The full model was built and simulated based on the data on Los Angeles County since January. In the model, the population was divided into four scenarios. Finally, according to this current model, a prediction of the future growing tendency of the different periods was made, which might show a clear performance of the spreading of the disease.

CONTACT

Mengyu Zhang
Email:
onezmy@g.ucla.edu
LinkedIn Website:
Linkedin | Mengyu Zhang

INTRODUCTION

To make a better simulation and prediction, the SEIR[1] model is selected to complete the modeling work based on the previous data. The SEIR model declares an individual health condition to a specific disease into four stages: susceptible, exposed, infection, and removed, which is just like the separation of coronavirus and proper to make a simulation. By initializing four periods of the spreading of the virus, based on the data from Los Angeles County[2], the parameters are simulated and analyzed. The result of the model showed the performance and prediction of epidemic development.

METHODS AND MATERIALS

According to the basic principle of SEIR Model, the Individuals are divided into 4 periods:
S(t): Susceptible. Individuals not yet infected with the disease.
E(t): Exposed. Individuals have been infected but are not yet infectious themselves.
I(t): Infections. Individuals have been infected with the disease and may spread the disease to the susceptible group in a certain .
R(t): Removed. Individuals have been infected and then removed from the disease.

The other related parameters are:
α: Average transition rate, equals to the reciprocal of incubation period.
β: Average number of contacts per person per time.
γ: Average recovery(remove) time.
ε: The infectivity attenuation coefficient of the exposed population as compared to the existed infected population.
ω: The coefficient shows the efficiency of protective and isolation measures. Just take as 0.9 here.

Then the relation between all the population groups and parameters is as following:

$$\begin{cases} \frac{dS}{dt} = w\beta(\varepsilon E + I)S/N \\ \frac{dE}{dt} = w\beta(\varepsilon E + I)S/N - \alpha E \\ \frac{dI}{dt} = \alpha E - \gamma I \\ \frac{dR}{dt} = \gamma I \\ N = S + E + I + R \end{cases}$$

RESULTS

Based on the data of Los Angeles County (from January 1 ,2020, to October 27, 2020)[3] , the parameters are simulated with fourth order Runge-Kutta method, and has the following results:

α	β	γ	ε	ω
0.17	0.66	0.27	0.5	0.9

Using Rstudio (Version 1.3.1073) and the 'deSolve' package[4], the SEIR model was built and visualized.

The initial infected population was set as 8% population in Los Angeles, which was simulated to the daily data on November 12, 2020.

In the following plots, the x-axis is the number of days counted from November 12, and the y-axis is the proportion of specific groups.

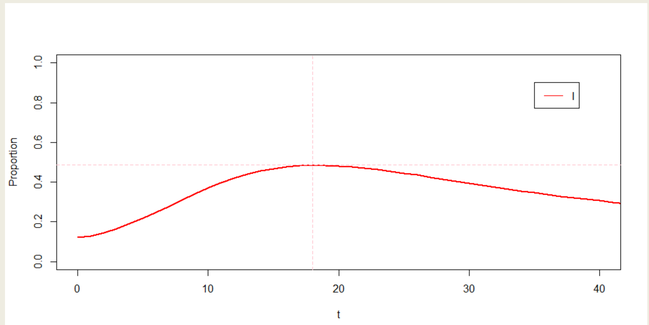

Figure 1: plot of predicted infected population proportion in LA

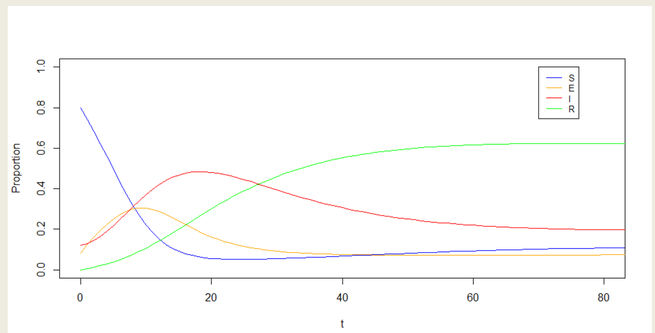

Figure 2: plot of predicted all four groups proportion in LA

CONCLUSIONS

Based on the simulated SEIR model, the visualized plot shows the following results:

- This model predict that there will be a rapid growth of the Infected population. If no more response solutions are taken by the local government or the residence, the infection number is likely to reach its maximum value in twenty days, which means that about half of the population will be infected.
- If the changing rate of the four groups is similar to data of the past nine months, the proportion is reaching an equilibrium condition after about two months. Although the removed(recovery) population has a much higher proportion than other groups, the infected population still takes the second-highest position.

DISCUSSION

According to the model, the following suggestion and defect are posed for a further discussion:

- The influence of county policy (**ω**) is still considered an uncertain parameter to the model. The value was taken as 0.9 because the COVID-19 policy in Los Angeles County was not as the cities' local policy in China which would be highly efficient to prevent the spreading of the coronavirus. According to the model, some self-protection behavior such as wearing mask to avoid exposure in public could reduce the coefficient which will efficiently help prevent the spread.
- Based on the previous data, the recovered people still has a lower probability to be infected again, which should be considered in the model. Residents in each county will have a better self-protection consciousness over time, which is also an unpredictable factor to the epidemic development.

SOURCES

1. Michael Y.Li, James S.Muldowney. Global stability for the SEIR model in epidemiology. March 1993,125(2):155-164. Available from: https://www.sciencedirect.com/science/article/abs/pii/0025556495927565
2. City of Los Angeles Public Health. LA County Daily COVID-19 Data. Available from: http://publichealth.lacounty.gov/media/coronavirus/data/index.htm
3. broadstreet COVID-19 data project. Race and Ethnicity Data. Available from: https://covid19dataproject.org/health-equity-release-notes/
4. Lloyd Chapman. SEIR model in R using deSolve. October 2018. Available from: http://epirecip.es/epicookbook/chapters/seir/r_desolve