Project Presentation

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In our project, we are going to talk about the MSIR model about chickenpox in Minnesota. In history, there are lots of diseases which threaten human’s life, for example, Black death, SARS, MERS and COVID-19. Numerous people are dead from those serious epidemics, however, people always find out how to overcome those diseases by medicine, vaccine and passive immunity. From this, we are curious about how passive immunity can affect the pandemic period.

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This report will make an MSIR model with mathematical modeling assumption on the epidemic. The Varicella data set provided by Minnesota will be used to analyze how the passive immunity affects our model. We will set the various situations for the MSIR model, and investigate how those changes affect the result. Varicella, also known as chickenpox, is highly contagious. This disease is more common in preschool and school age children. It spreaded by respiratory droplets and direct contact with skin lesions. Varicella was a serious epidemic before the vaccine was developed. There were about 4 million cases, 10,600 hospitalizations, and 100 to 150 deaths. However, the cases declined about 90% from 1995 to 2005.

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First, we need to set up modeling assumptions for our MSIR model. The real world data and data analysis might have some difference because there are numerous unexpected outside effects in the real world. Hence, we need to restrict our MSIR model on some conditions as below.

1. There should not be people who get other diseases. It causes a population change.

2. Ignore change in population due to immigration and emigration. It causes a population change.

3. Can never become susceptible again. We assume people get perfect immunity when recovered.

4. Constant rate of infectivity

5. The population is homogeneous.

6. No isolation, No vaccination.

7. Only people can spread disease (not animals).

Also there is some weakness in our MSIR model. First, we assumed that the population is homogeneous, so there will be some error when we apply real world data. Second, the MSIR model would not be suitable if the population levels are small.

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In the MSIR model, we are looking for the change or impact of four groups of population under given time. At the start, we have four groups which are M, S, I and R. M is passively immune class, S is susceptible class, I is infectious class and R is recovery class. All populations have to flow from M to R as like the figure below. Unlike the original SIR model, there will be births and deaths added to the compartments.

• The Passive immune compartment consists of those individuals who have never been infectious and have immunity of the disease. This will skip the infectious class and move on to the recovery group.

• The susceptible compartment consists of those individuals who have never been infectious but capable of getting the disease and becoming infectious. This group would move into the infectious group if infected.

• The infectious compartment consists of those individuals who are infectious and capable of transmitting the disease to the susceptible group. Infectious groups will remain in this group for a given period and will be moved onto the recovery group.

• The recovery compartment consists of those individuals who had the disease and are dead, or have recovered and are permanently immune from the disease.

And then, we will set the parameters for our MSIR model as follows.

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We will set Birth rate as alpha, Death rate as miu, Rate of non-passive immune people as omega, Rate of infectivity as beta and Recovery rate as gamma. Since we are looking for the M,S,I,R change with the unit time, we have to make the system of differential equations for the numbers in the epidemiological classes and the population size as the following equation.

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Now, in our MSIR model, we will change some parameters to find out which parameter affects our MSIR model. We will use the following 4 questions to find out those differences effectively.

1. When is the disease spreading most rapidly?

2. When is the disease decreasing most rapidly?

3. On what day did the epidemic reach its peak and what percentage of people were infectious on that day?

4. What percentage of the population got infectious during the outbreak?

And then we set our initial parameters as follows.

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We set our birth rate, death rate, and total population from data of Minnesota and Infectivity rate, Recovery rate and immune rate from other documents in our reference page.

Now we made some changes in birth rate, infectivity rate, recovery rate and immune rate. The result of those parameter changes is as follows.

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When we change the birth rate, as we can see in the table, high birth rate affects the infectious rate on peak day. This makes sense because when the population increases, the probability of infection will also increase.

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When we change the infectivity rate, as we can see in the table, higher infectivity rate makes the spread of chicken pox faster. Also, the total infected population is increasing.

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When we change the recovery rate, as we can see in the table, high recovery rate decreases the percent of infectious on peak day and also decreases the total population got infected during the epidemic.

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Last, when we change passive immune rate, low passive immune rate decreases the percent of infectious on peak day and also decreases the total population got infected during the epidemic.

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Now, we are going to compare our MSIR model with the original SIR model using the same parameters which we used in our MSIR model. We can get the result from the following table.

As we can see in the table, the Chicken pox spread faster in Origianl SIR model and more population are infected. From this, we can see that if we have a passive immune class during the outbreak, we can suppress the spreading of disease and also we can protect some people from the disease.

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From our MSIR model analysis, we can find out that the passive immune class suppresses the spreading of disease. Also, we need low birth rate(α), low infectivity rate(β), high recovery rate(γ), and low passive immune rate(Ω) to suppress an epidemic. This result shows how important getting a vaccine and having passive immune is. We can use this analyzed data for the future work.

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We can try SIR model with the vaccination or SIR model with isolation, and find out if having passive immune is powerful, or either doing vaccination or isolation is powerful for suppressing the spread of disease. After that we can try the MSIR model with vaccination or MSIR model with isolation, and see how well it suppresses the spread of disease.