The spread and eradication of Ebola

Meng Li[1, a]

[1]School of Electrical Engineering, North China Electric Power University, Baoding 071000, China

[a]295273953@qq.com

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Abstract. The world medical association has developed new medication to stop Ebola and cure patients whose disease is not advanced. In order to offer an optimal plan to optimize the eradication of Ebola, we establish a mathematic model based on the spread of Ebola virus disease. The first model is based on Susceptibility Infection and Removal model (SIR) to analyze the spread of Ebola. Through the curve of the epidemic, we draw a conclusion that decreasing the contact rate or increasing the cure rate is efficient measure to optimize the eradication of Ebola.

1. Introduction

Ebola is a big event in World Public Health Field in 2014[1]. It is worth to take Ebola virus disease(EVD) as an example to discuss the spread of infectious disease and take relationship between the quantity of the medicine needed, speed of manufacturing of the drug and the effect of eradicating the Ebola into consideration.

2. Model for eradication of the spread of Ebola virus disease

2.1 Model assumption

We propose specific assumptions:

The data we obtained is realistic and reliable. The crowd of people we researched is an ideal crowd which means there are no migrants and out-migrants.

There are no death of other causes.

2.2 Model Processing

Based on comparing the range of cases and deaths in Guinea and Sierra Leone[2.3], we could discover that although the speed of infection rate and prevalence rate in two countries are various, the trends are similar which can represents the trend of the Ebola epidemic. So we refer to the Susceptibility Infection and Removal model (SIR) [4]to build our model.

Guinea：

$$N = 1120.3w$$

$$s_0 = 1120w \text{ ; } \quad i_0 = 2917 \text{ ; } \quad r_0 = 0 \text{ ;}$$

Sierra Leone：

$$N' = 548.5w$$

$$s_0' = 547.4w \text{ ; } \quad i_0' = 10518 \text{ ; } \quad r_0' = 0 \text{ ;}$$

$$\sigma = \frac{\mu}{\lambda} \tag{1}$$

$$s(t) + i(t) + r(t) = N \tag{2}$$

Based on Susceptibility Infection and Removal model (SIR)

$$\begin{cases} \frac{ds}{dt} = -\lambda si, s(0) = s_0 \\ \frac{di}{dt} = \lambda si - i\mu, i(0) = i_0 \\ \frac{dr}{dt} = i\mu \end{cases} \tag{3}$$

We can get the formula through (2) and (3)

$$s(t) = s_0 e^{-\frac{r}{\sigma}} \tag{4}$$

Based on the formula of Taylor Expansion and the Change, we can get the rate of change in number of people:

$$\frac{dr}{dt} = \frac{\mu\alpha^2\sigma^2}{2s_0} \bullet \frac{1}{ch^2(\frac{\mu\alpha t}{2} - \varphi)} \tag{5}$$

Special note:

$$\alpha = \left[(\frac{s_0}{\sigma} - 1)^2 + \frac{2s_0 i_0}{\sigma^2} \right]^{\frac{1}{2}}$$

$$\begin{cases} \frac{ds}{dt} = -\lambda si, s(0) = s_0 \\ \frac{di}{dt} = \lambda si - i\mu, i(0) = i_0 \end{cases} \tag{6}$$

We can take the change of（6）to get the formula (7)

$$i(s) = i_0 + s_0 - s + \sigma \ln \frac{s}{s_0} \tag{7}$$

We can obtain the formula through (7):

$$\frac{di}{ds} = \frac{\sigma}{s} - 1$$

Base on the information which is offered by Wikipedia to collect the appropriate data:

Table 1: the global cases and deaths form 18 Nov 2014 to 18 Jan 2014

Date	Case	Death	Date	Case	Death
2014.11.18	2047	1214	2014.12.21	2597	1607
2014.11.23	2134	1260	2014.12.28	2707	1708
2014.11.30	2164	1327	2015.01.04	2775	1781
2014.12.07	2292	1428	2015.01.11	2806	1814
2014.12.14	2416	1525	2015.01.18	2871	1876

Based on the above formulas we choose week as the unit time and then calculate the average contact rate and cure rate per week in Guinea and Sierra Leone:

3. Results

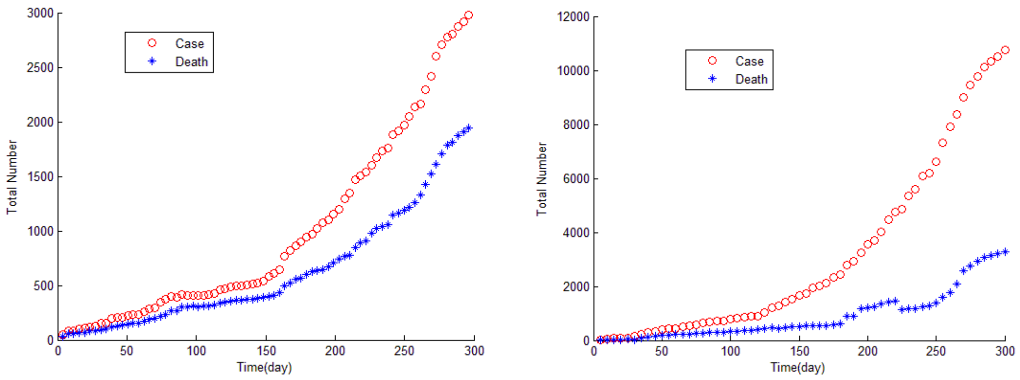

Figure 1: the range of cases and death in Guinea and Sierra Leone

Draw phase trajectories through change the value of σ:

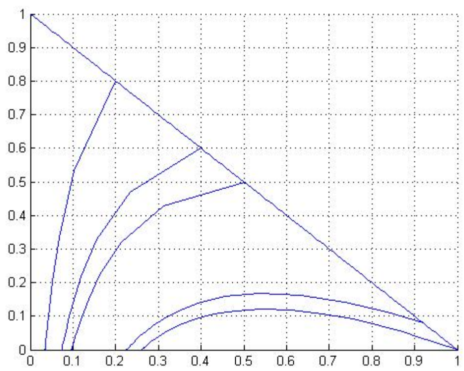

Figure 2: phase trajectories

When $s_0 > \sigma$; the value of $i(t)$ rise at first and then falling to zero;

When $s_0 < \sigma$; $i(t)$ falling monotonously to zero;

We define σ as threshold and get the relationship of σ and s_0.

Calculate the average contact rate and cure rate per week in Guinea and Sierra Leone:

$$\lambda = 10.5, \quad \mu = 0.354;$$

$$\lambda' = 10.5, \quad \mu' = 0.455;$$

Draw Guinea Ebola virus disease infection predict trends:

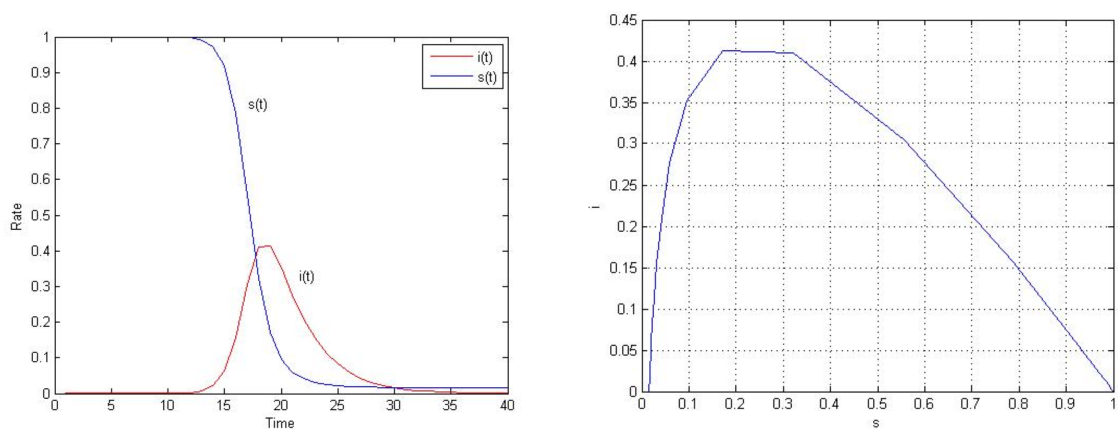

Figure 3: the predict trends of virus disease infection in Guinea Ebola:

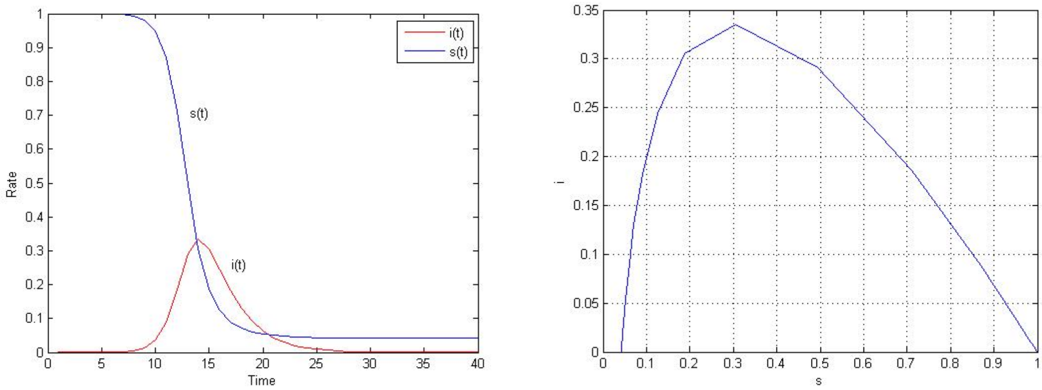

Figure 4 predict trends of virus disease infection in Sierra Leone

4. Results

Through figure 1 we can discover that without the good treatment with cure drug, the number of susceptible people decreases gradually and the infected people increase gradually and reach the maximum in a certain period.

In the situation we haven't take direct measures such as transport the latest cure drugs to the infected area, we found the Ebola virus disease has exponential growth trend in a certain period which has threaten the health of susceptible people seriously.

Ebola virus disease spread fast and mortality rate is high. If Ebola isn't under control, there will be a greater outbreak with the increase in this situation.

We can get method to control the spread of Ebola efficiently through the figure 2 and the formula (7). Since the initial value of infected people is hard to change, we need to increase the value of threshold σ which means decrease the contact rate per week λ or increase the cure rate per week μ.

We can decrease the contact rate per week λ by insulate the infected people and increase the cure rate per week μ through increasing the manufacture of drugs, take good treatment to decrease the quantity of drugs needed and optimize the transportation system. We will analysis those optimal measures in model two and model three.

References

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